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Major P. A. MACMAHON, D.Sc., Sc.D., LL.D., F.R.S., PRESIDENT, in the Chair.

Charles Frederick Butterworth, Waterloo, Poynton, Cheshire;
Mark Herbert Rollason, B.Sc. (Lond.), 6 Osborne Road, Chester-le-Street, Co. Durham; and
Dr. Gustaf Strömberg, Solar Observatory, Mount Wilson, California, U.S.A.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Theralandoor Panchapagesa Bhaskara Shastri, M.A., Assistant, Nizamiah Observatory, Hyderabad, Deccan, India (proposed by Ahmed Hussain);
Miss Agnes Fry, Failand House, Failand, near Bristol (proposed by W. F. Denning);
Henry Bedingfield Goodwin, Retired Naval Instructor, Royal Navy, 153 Norbury Crescent, Norbury, S.W. 16 (proposed by Major P. A. MacMahon);
Clarence Victor Grant, B.A. (Cantab.), Schoolmaster, Kirmington, Brocklesby, Lincolnshire (proposed by W. H. Pick);
Horace Lamb, M.A., Sc.D., D.Sc., LL.D., F.R.S., Professor of Mathematics in the University of Manchester, 6 Wilbraham Road, Fallowfield, Manchester (proposed by H. H. Turner);
William Patrick Dartrey MacMahon, Royal Marine Artillery, Eastney Barracks (proposed by Major P. A. MacMahon);

S. B. Mattey, B.Sc., Corporal R.E., 32 Heavitree Road, Plumstead, S.E. 18 (proposed by W. F. Denning);

George Frederick Simpson, B.A., Lieut. R.G.A., Daneholm, Alexandra Park, Manchester (proposed by Charles G. Falkner);

Walter Robert Stokes, 53 Finsbury Park Road, London, N. 4 (proposed by W. S. Franks); and

James Watt, Writer to the Signet, 24 Rothesay Terrace, Edinburgh (proposed by R. A. Sampson).

Mr. David Baxandall, Mr. W. B. Gibbs, and Mr. H. P. Hollis were appointed Auditors of the Treasurer's accounts for the year 1918.

Forty-five presents were announced as having been received since the last meeting, including, amongst others—

G. R. Kaye, The Astronomical Observatories of Jai Singh, presented by the Author.

The Evolution of Binary Systems.
By J. H. Jeans, M.A., F.R.S.

1. It is a fundamental fact of stellar dynamics that adjacent stars interfere to only an infinitesimal extent with one another's motion; the alterations in a star's motion must be ascribed to the gravitational forces of the universe as a whole.* These latter forces can have only an infinitesimal effect on a star's angular momentum, whence it follows that the angular momentum of a star, or stellar system, must remain very approximately constant.

Assuming this constancy of angular momentum, it is well known that the angular momentum of our solar system is too small for the system to have broken up by rotation. This difficulty has been amply discussed; the present paper deals with a similar difficulty which has hardly been discussed at all, namely, that the angular momentum of the majority of binary systems is too large for them to have broken up by rotation.

2. Let us first put the problem in exact mathematical form. Let the two constituents of a binary star be of masses M, M′; let them describe about one another an elliptic orbit of eccentricity e, semi-major axis a, and semi-latus rectum l, the latter being given by $l = a(1 - e^2)$.

If the stars were spheres or points, their attraction when at distance r would be MM'/r^2. To allow for the departure from the spherical shape produced by their mutual tidal action, we must replace this expression by

$$\frac{MM'}{r^2}(1 + \zeta)$$

* *M.N.*, 74 (1913), 109, or Eddington's *Stellar Movements*, chap. xii.

where ζ is identical with the ζ of Sir G. Darwin's papers.* For all shapes of the constituent masses which are physically possible, the value of ζ is positive and small.

The orbital momentum of the binary system is

$$\frac{MM'}{(M+M')^{\frac{1}{3}}}(1+\zeta)^{\frac{1}{3}}l^{\frac{1}{3}} \quad . \quad . \quad (1)$$

The total angular momentum is of course obtained by adding to this the rotational momenta of the two constituents, which may be expressed in the form

$$Mk^2\omega + M'k'^2\omega' \quad . \quad . \quad . \quad (2)$$

Except in so far as the angular momentum of a binary star is disturbed from outside, the sum of expressions (1) and (2) must remain constant throughout the whole course of a star's evolution.

Consider now a binary star in which the components are separated by not less than about three diameters of the greater mass. It is readily seen that ζ is infinitesimal, while expression (2) is negligible in comparison with expression (1). Thus the whole angular momentum reduces to

$$\frac{MM'}{(M+M')^{\frac{1}{3}}}l^{\frac{1}{3}} \quad . \quad . \quad . \quad (3)$$

This must remain constant throughout the whole subsequent evolution of the star, whence, since M, M′ separately remain constant, it follows that l must remain constant. Thus for stars whose components are not within a very few diameters of one another, this including all visual and most spectroscopic binaries, the latus rectum is permanently fixed for all time.

Results only slightly less definite can be obtained when we consider stars almost in contact. Here ζ is not negligible, but its value is known to be always less than 0·22. The rotational momentum given by formula (2) is not negligible, but is only a small fraction of the orbital momentum, except for a star whose components are of very unequal mass. Russell, who has examined this question in detail, † finds that for a binary which has divided into two approximately equal parts by fission, the semi-latus rectum cannot increase by more than 60 per cent. throughout the whole life of the star.

Thus the teaching of dynamical theory is quite definite. So long as a binary star remains unaffected by the forces from other stars, the semi-latus rectum of its orbit remains approximately unaltered. The period depends both on the semi-latus rectum and on the eccentricity, but if we exclude the few stars which have high eccentricity of orbit, we may say that the period also must remain approximately unaltered through the whole course of evolution of the star.

* *Coll. Works*, 3, 436, or *Phil. Trans.*, A, 206 (1906), 261. See also H. N. Russell, "On the Origin of Binary Stars," *Ap. J.*, 31 (1910), 185.

† *L.c. ante*, p. 191.

3. Observation reveals binary stars of periods ranging from a few hours to hundreds of years. Campbell * has shown that the period shows marked correlation with the eccentricity of the orbit and the spectral type of the star, the longer periods and higher eccentricities belonging to stars of advanced spectral type. Campbell suggests as an explanation that the evolution through the various spectral types was accompanied by a continual increase of period, the period lengthening to thousands of times its initial value under the influence of tidal friction. This explanation is, as we have seen, untenable. The only agency which is capable of lengthening the period of a binary star to any great extent is interaction with other stars.

At this stage only two hypotheses seem to be consistent with dynamical theory:

(A) The periods and dimensions of orbits of binary stars are permanently fixed, and have retained approximately their present values through the whole of the star's life.

(B) The periods and dimensions of orbits of binary stars, although now definitely fixed, have been determined as the result of interactions with other stars in some past epoch in which these interactions were not negligible.

Hypothesis (A) needs only to be examined to be instantly dismissed. Russell's well-known investigation on the orbits of binary and triple systems † provides almost incontrovertible proof that the majority of such systems have originated by fission. If the periods have remained fixed, or approximately fixed, ever since fission took place, the density of the mass at fission can be calculated from a knowledge of the present period. For binaries whose period is measured in years, this density is found to be excessively low, ‡ being, in fact, so low as to show that the star could not have originated by fission at all. To take a definite instance, α Centauri has at present a period of 81·2 years. Allowing for its eccentricity of orbit ($e = 0{\cdot}53$), we find that, if the star has been kept free from disturbance by other stars, its period at fission cannot have been less than 20·4 years, and its density at fission must have been less than 6×10^{-11}. A mass of density so low as this cannot be expected to break up by fission at all, for only comparatively dense and fairly homogeneous masses are believed to break up by fission. Thus we are driven to supposing that the period of α Centauri has been lengthened by encounters with other stars.

4. We accordingly adopt hypothesis (B). To see exactly what is implied in this, consider two definite stars, β Lyræ of period 12·9 days and α Centauri of period 2300 times this, or 81·2 years. A widely accepted view is that β Lyræ will in time develop into a system similar to α Centauri, but this view has been seen to be untenable on dynamical grounds; such a development would

* "Second Catalogue of Spectroscopic Binary Stars," *L.O.B.*, 181 (1910), or *Stellar Motions*, chap. viii.

† *Ap. J.*, 31 (1910), 185.

‡ Moulton, *Carn. Inst. Publication*, 107, 133.

require about a 12-fold increase of angular momentum, and there is no source of new angular momentum available. Our hypothesis (A), which has also been seen to be untenable, involves that β Lyræ and α Centauri are two distinct classes of objects. Our hypothesis (B) supposes, in conformity with dynamical theory, that β Lyræ can never develop into a long-period system like α Centauri, but also supposes that α Centauri may have developed out of a system similar to β Lyræ in some earlier epoch, when stellar encounters at fairly close distances were events of common occurrence.

5. Let us examine what may be expected to happen to a number of binary stars when encounters at close distances are of such common occurrence that the system may be supposed to assume a final steady state. Let u, v, w be the components of the velocity in space of the centre of gravity of any binary star, and let r, θ, ϕ be the polar co-ordinates of one component M relatively to the second component M′. The total kinetic energy of the binary system is

$$\tfrac{1}{2}(\mathrm{M}+\mathrm{M}')(u^2+v^2+w^2)+\tfrac{1}{2}\frac{\mathrm{MM}'}{\mathrm{M}+\mathrm{M}'}(\dot{r}^2+r^2\dot{\theta}^2+r^2\sin^2\theta\dot{\phi}^2) \quad (4)$$

After a sufficient number of encounters, we know, from the general principles of statistical mechanics, that the average value of each of the six terms in this sum must be the same. When the binary system comes into being as a result of fission, the value of $\dot{r}^2$, the square of the radial velocity, will be very small, while the value of $r^2\dot{\theta}^2+r^2\sin^2\theta\dot{\phi}^2$, the square of the tangential velocity, will bear no relation either to $\dot{r}^2$ or to $u^2+v^2+w^2$, the square of the translational velocity of the system. The tendency of encounters is to equalise all the terms in formula (4), and in the final state which would be attained after an infinite number of encounters, the mean square of the tangential velocity would be equal to twice the mean square of the radial velocity, and would also be equal to $\frac{2}{3}(\mathrm{M}+\mathrm{M}')^2/\mathrm{MM}'$ times the mean square of the velocity of translation in space.

6. Consider a single orbit of eccentricity e and semi-latus rectum l. Let h be the constant value of $r^2\dot{\theta}$, the rate of description of double areas. Denote average values taken with respect to the time through any number of complete periods by a bar, then we readily find

$$\overline{\dot{r}^2}=\frac{h^2}{l^2}\left[1-(1-e^2)^{\frac{1}{2}}\right]$$

$$\overline{r^2\dot{\theta}^2+r^2\sin^2\theta\dot{\phi}^2}=\frac{h^2}{l^2}(1-e^2)^{\frac{1}{2}}.$$

Thus for a single orbit the mean square of the tangential velocity will be equal to twice the mean square of the radial velocity if

$$(1-e^2)^{\frac{1}{2}}=2-2(1-e^2)^{\frac{1}{2}}.$$

The root of this equation is found to be

$$(1-e^2)^{\frac{1}{2}} = \cdot 7709, \qquad e = \cdot 6370.$$

Thus in every binary whose eccentricity of orbit is less than ·637 the general effect of encounter is to increase the eccentricity, while the effect on binaries of eccentricity greater than ·637 is to decrease their eccentricity. Binaries start life with very small eccentricity of orbit, so that the general effect of encounters must be an increase of eccentricity until the eccentricities are ranged around the value 0·637. It must, however, be noticed that we have not proved that the arithmetic mean of all eccentricities will be 0·637.

Doberck,* quoted by Campbell, gives 0·62 for the mean eccentricity of long-period binaries (period above 120 years, mean 206 years). Campbell finds only 0·495 for the mean eccentricity of fifty stars of well-determined orbits, all these being of period less than 200 years. The limitation to well-determined orbits is likely to exclude a number of stars of long period and high eccentricity, so that this procedure may be expected to give too low a value for the mean eccentricity. Campbell states that the addition of a third group of stars of somewhat more uncertain orbits and of assigned periods greater than 200 years would cause the mean eccentricity to approximate to 0·6.

7. Let P denote the period of an orbit, and C^2 the mean square velocity of translation in space. Then the final relation between P and C^2 must be such that the mean square of the tangential orbital velocity must be equal to $\frac{2}{3}(M+M')^2/MM'$ times C^2. This is found to give the relation

$$\left[\frac{2\pi\gamma(M+M')}{P}\right]^{\frac{2}{3}}(1-e^2)^{\frac{1}{2}} = \frac{2}{3}\frac{(M+M')^2}{MM'}C^2 \quad . \quad . \quad (5)$$

Since this equation does not depend largely upon e, let us give to e its equipartition value ·6370 and so put $(1-e^2)^{\frac{1}{2}} = \cdot 7709$. Clearly the value of P will be very small when M and M′ are very unequal; but binaries for which M and M′ are very unequal are unknown. Let us for simplicity put $M = M'$, noticing that so long as M and M′ are fairly equal, P hardly depends at all on the ratio of M to M′. With these simplifications, equation (5) becomes, very approximately,

$$P = \frac{\gamma(M+M')}{C^3} \quad . \quad . \quad . \quad (6)$$

This gives the mean period in the final equipartition state. In this state $M+M'$ and C are themselves correlated, the mean value of $(M+M')C^2$ being the same for all types of stars. Thus we may say that P will vary either as C^{-5} or as $(M+M')^{\frac{5}{2}}$.

For a type of star of mass equal to that of our sun ($M+M' = 2\times 10^{33}$) and of mean-square velocity $C = 25$ kms. a second, formula

* *Ast. Nach.*, 147 (1898), 251.

(6) gives $P = 8{\cdot}3 \times 10^6$ secs. = about 96 days. For an average B-type binary we may perhaps take $M + M'$ equal to ten times the sun's mass,* and C equal to only 8 kms. a sec.; the value of P is found to be about 80 years.

8. From these calculations it appears that even an unlimited series of encounters with other stars will not increase the eccentricities or periods of binary orbits indefinitely. A limit is reached when the eccentricities average 0·6370, and when the periods are measured in years or centuries. Thus we may suppose the long-period variables to have had their orbits pulled about to an unlimited extent by encounters with other stars: these are almost universally stars of advanced spectral type. On the other hand, the short-period binaries, which are generally of early spectral type, must be supposed to have been born subsequently to the epoch in which close stellar encounters were of common occurrence. To return to our previous illustration, α Centauri, with its period of 81 years and its eccentricity 0·53, may well have lived as a binary star through a long series of stellar encounters; β Lyræ, and with it a whole group of early-type short-period binaries of low eccentricity, must have been born since encounters ceased.

Conclusion.

9. We have found that there is only one hypothesis which is capable of reconciling the facts of observational astronomy with dynamical theory. It is that the present epoch in the history of our universe was preceded by one in which the stars were much more closely packed than they now are, so that stellar encounters at fairly close distances, instead of being rare events of negligible frequency, were events of comparatively common occurrence. Such encounters must have increased the eccentricities and periods of our long-period binaries to their present values; from now on the periods both of these and of the short-period binaries are likely to vary but little.

The main hypothesis, that the stars were formerly closer together than now, is not difficult to accept. If we suppose the stars to have been formed by a process of nebular condensation, it becomes almost inevitable. If the stars, with their present spacing, were redissolved into a continuous nebular mass, the mean density of this nebula would be of the order of 10^{-23} only. Now the average mass of stars formed by gravitational condensation out of a continuous nebular mass depends upon the density of the nebula, and masses comparable with those of our sun and stars would be formed out of a nebula of density of the order of 10^{-19}. The hypothesis of nebulous origin commits us to the supposition that our universe must have expanded by at least about ten diameters since its nebular stage. It is open to question whether this expansion is not still going on. The observed positive excess of radial velocities of stars of all types, particularly the 5 kms. a sec. excess velocity of

* Halm, *Ap. J.*, 71 (1910), 634.

the B-type stars, is most naturally interpreted as an expansion taking place now before our eyes.

We suppose the longest period binaries to have lived through sufficient of this earlier epoch for equipartition of energy to have been established, or approximately established, in their internal degree of freedom. It follows that equipartition ought also to have been established as regards their motion of translation in space. This is probably the case; the dwarf M-stars have velocities which show no preference for particular directions in space, and there seems to be no correlation between the magnitude of their velocities and the parts of the universe they occupy. The old objection that the present spacing of the stars leads to a "time of relaxation" of the order of 10^{14} or 10^{16} years is removed by our main hypothesis.

On the other hand, the short-period binaries, which are mainly early type stars, cannot have lived through this earlier period as binary stars. The circumstance that they largely fall into undissolved moving clusters of stars having a common velocity in space leads us still further and suggests that these early type stars cannot have existed at all during the early period. We are led to regard the B-type stars and short-period binaries as of more recent birth; neither in their velocity of translation nor in their internal motions do they show evidence of encounters with other stars. They are mainly still close to the galactic plane in which we must suppose them to have been born; they were perhaps the last stars to be born out of the rotating nebula which we may suppose to have been the parent of our system of stars.

On a Certain Relation between the Elements of Planets and Satellites. By R. J. Pocock, B.A., B.Sc., F.R.A.S.

[*Note by H. H. Turner.*—This note was found among Mr. Pocock's papers after his death, and was sent me by Mrs. Pocock with the remark that it was her husband's wish to have all his papers published. The note is slight, and from the fact that it was not sent to the Society with the batch of others which reached us in time for the November number, I doubt whether it was intended for the *Monthly Notices*. The addition of the letters F.R.A.S. to the author's name (which have been left as written) also seems to suggest that the paper had some other intended destination. But under the circumstances of the author's sudden and unexpected death, considerations of this kind may appropriately be waived.]

1. The following empirical formula is given by M. F. Ollive in *Comptes Rendus*, **157**, No. 26, p. 1501, and quoted in *Nature*, **92**, 724, and *Journal Astronomical Society of India*, **4**, 159, viz.: —Let R′ represent the mean distance of a satellite from its

primary, V its orbital velocity, R the mean distance of the planet from the Sun, and r its mean radius, then

$$r^3 = \mathrm{K} \,.\, \mathrm{R} \,.\, \mathrm{R}' \,.\, \mathrm{V}^2 \quad . \quad . \quad . \quad . \quad (1)$$

where K is a constant.

2. If K is chosen so that the formula fits accurately in the case of the Earth, it is found to give fairly good values of r in the cases of Mars, Jupiter, and Saturn, but quite erroneous values in the cases of Uranus and Neptune. We may remark that the two sides of the equation (1) may differ by about 20 per cent., and yet the deduced value of r will only be in error by about 6 per cent. The proper test of the value of the relation is therefore not the deduced values of r, but the consistency of the values of K for different planets. We shall consider the formula from another point of view, however.

3. If P is the period of any satellite about its primary, and M the mass of the primary, we have by Kepler's third law, neglecting the mass of the satellite,

$$k \,.\, \mathrm{M} \,.\, \mathrm{P}^2 = \mathrm{R}'^3 \quad . \quad . \quad . \quad . \quad (2)$$

where k is a constant for all satellites and planets.

But we have also, neglecting the eccentricity of the satellite's orbit,

$$2\pi \mathrm{R}' = \mathrm{V} \,.\, \mathrm{P} \quad . \quad . \quad . \quad . \quad (3)$$

Hence from (1), (2), and (3), we have

$$r^3 = \mu \,.\, \mathrm{R} \,.\, \mathrm{M} \quad . \quad . \quad . \quad . \quad (4)$$

where μ is a constant.

4. Now this formula (4), which we have shown to be equivalent to (1), does not involve the elements of the satellites at all, and the formula is one between certain planetary elements only; it is therefore not surprising that the results from different satellites of any one system are highly consistent among themselves—it is essentially necessary that they should be so.

5. Considering now the formula (4), if D represents the density of any planet, $\mathrm{M} \,.\, \mathrm{D}^{-1}$ is proportional to r^3, and we may therefore write the relation in the form

$$\mathrm{D} \,.\, \mathrm{R} = \text{const.} \quad . \quad . \quad . \quad . \quad (5)$$

where D is the density of any planet and R is its distance from the Sun.

Now we know that the density of the further planets is on the average less than the density of the nearer planets, and the law (1) is therefore nothing more than a mathematical statement of this fact.

6. Although on the average the density diminishes as we recede from the Sun, it does not vary in the regular manner suggested by the law (5), which is merely a rough approximation for the four middle planets, and breaks down altogether at the two

extremities. Taking the distances and densities of the planets from Moulton's *Descriptive Astronomy* (pp. 141 and 146), we form the following table, in which the densities are given in terms of that of water and the distances in millions of miles.

Planet.	Density D.	Distance R.	Product D.R.
Mercury	3·70	36	133
Venus	4·89	67	328
Earth	5·53	93	514
Mars	3·95	142	561
Jupiter	1·53	483	739
Saturn	0·72	886	638
Uranus	1·22	1782	2170
Neptune	1·11	2792	3100

Slight alterations in the adopted densities of some of the planets might improve the accordance of the last column somewhat, but there is no possibility of bringing Mercury, Uranus, or Neptune into agreement with the rest.

7. The formula (1) must therefore be considered as given in its simplest form by (4) or (5), and as applying to planetary elements only; it must, moreover, be considered as only an approximate formula for the middle planets, which happens to hold for these planets owing to the fact that for them the density diminishes as the distance increases.

Nizamiah Observatory, Hyderabad:
1918 *March* 30.

Observations of the Magnitude of Nova Aquilæ, 1918, *made at the Radcliffe Observatory, Oxford; and a Comparison with the Radcliffe Magnitudes of Nova Persei*, 1901. By Arthur A. Rambaut, M.A., D.Sc., F.R.S., Radcliffe Observer. (Plate 1.)

The first information of the discovery of a new star in Aquila received at this Observatory was derived from the morning papers of June 10. The same morning we received a telegram from Mr. H. G. S. Barrett, of this Observatory, who had been absent since the middle of January on military service in London. It ran as follows:—"Nova, magnitude nought, 18 degrees right, same altitude nearly as Alpha Aquilæ. Have you any information? Sky clouded before definite observations secured." The telegram refers to the night of June 9, and shows that on that evening Mr. Barrett independently discovered the object. Under the circumstances to have recognised it as a new star as seen from the streets of London, at a low altitude in a bright sky not entirely

free from haze, and without the help of star-charts, was, I think, a very creditable performance.

Mr. Barrett's account of his first observation is as follows:—

"The Nova was first seen on Sunday at 9.15 G.M.T. from Hyde Park, London. At this time it was very low in the sky, and no certain identification being possible owing to the fewness of the stars visible in the bright sky, was at first assumed—but with considerable doubt, especially having regard to its brightness, which was superior to Vega, in spite of its being of very much lower altitude—to be α Aquilæ.

"Definite observations of brightness were not attempted at this time owing to the character of the sky and the unfavourable position of the object. Walking from Hyde Park to Chelsea, I was able to keep it almost constantly in view, and was able definitely to class it as a strange object. On reaching my quarters I made the following observations:—

G.M.T.	Mag.
10.10	0·5 brighter than α Lyræ
	1·0 ,, ,, α Aquilæ.

"By this time clouds—rendering the above observations of second-rate value only—began spreading over, and no further observations were possible."

Mr. Barrett also observed the star on June 10, 14, 15, and 16. His resulting magnitudes are included in Table II., and his remarks in the table of "Observers' Notes" below.

At the Radcliffe Observatory the first observations of the Nova were made on June 11, and observations have been continued up to the present date, the whole series comprising 153 sets (641 separate comparisons) on 98 nights. Strong twilight prevailed during most of the earlier observations, while the Nova was still a bright object and easily comparable with the few available bright stars.

The proportional method of determining magnitude was for the most part followed, the Nova being compared with two stars, one brighter and one fainter, and an estimate made of the ratio which the difference in brightness between each comparison star and the Nova bore to the difference in brightness of the two comparison stars.

At first the observations were made with the naked eye only. Slight optical aid was introduced occasionally from June 24, and in all cases from August 12 onwards. The instruments used are indicated in column 3 of Table II. by the letters *n*, *f*, *b*, and *m*, where

n denotes the naked eye,
f a pair of Ross's field-glasses lent by Captain G. M. Rambaut,
b a pair of opera-glasses (Galilean), the property of Dr. Rambaut,
and *m* a monocular (Galilean) belonging to the Observatory.

In the course of the observations two stars, η Serpentis and δ Aquilæ, frequently used as comparison stars, were found to differ sensibly in magnitude, whereas the *Revised Harvard Photometry* makes them practically equal, the magnitude there given being 3·42 mag. and 3·44 mag. respectively. On one occasion (1918 July 6) they were independently observed to be sufficiently separated in brightness to allow the Nova to be placed between them, the recorded observations being "η Serpentis 1 Nova 4 δ Aquilæ" (A.A.R.) and "Nova half-way between η Serpentis and δ Aquilæ, *i.e.* fainter than η and brighter than δ" (R.). The discrepancy could not be due to atmospheric absorption, since the differential corrections for this effect are insensible. It may perhaps be partly attributable to a slight difference of colour in the two stars, which are given in the H.P. as Y (topaz yellow) and *y* (yellow) respectively. In the H.R. their spectra are classed as K and F respectively.

From a discussion of the present series of observations we find the following magnitudes for these two stars :—

	η Serpentis.		δ Aquilæ.	
Obser.	Mag.	No. of Comparisons.	Mag.	No. of Comparisons.
A.A.R.	3·33	9	3·58	6
R.	3·34	17	3·51	22

which are in closer agreement with the values given in the H.P., viz. :—

3·35 and 3·46

than with those of the H.R., namely,

3·42 and 3·44.

The discordances, although small, suggest a slight variability in one or both of the stars.

The character of the image of the Nova was examined with the 10-inch Barclay refractor on June 22, July 3, 26 and 31, and on November 27 (see "Observers' Notes"). On the first four of these dates the image at the normal stellar focus exhibited the ruby marginal fringe characteristic of new stars. When examined on November 27, the image at the usual focus was noted as "colourless."

On June 11, both with the naked eye and with field-glasses, the character of the image resembled those of Altair and Vega, but was much more sparkling than Arcturus. On that date "the comparison of the Nova with Arcturus for magnitude was difficult on account of the reddish colour of the latter." In contrast with this, only four nights later, on June 15, the new star was remarked as "slightly reddish and very similar in colour to Arcturus." This comparatively sudden change of colour had its counterpart in the case of Nova Persei, which was noted as "bluish white" when we first saw it (*i.e.* on 1901 February 25), and "reddish yellow" on

March 1 (four nights after). The reddish colour of Nova Aquilæ gradually deepened until July 10, when it was "very red," but on July 12 it was "not so red as on the 10th." After this date the colour became much less pronounced, inclining to yellow, and on November 27 (as stated above) the image was found to be colourless. The observations of Nova Aquilæ have not revealed any decided changes of colour synchronising with the periodic variations in its brightness, such as were found in the case of Nova Persei.

With regard to the *periodic* variations in the brightness of Nova Aquilæ, the table below (Table A) may be of interest. It is constructed on much the same plan as Professor E. C. Pickering's Table VII. for Nova Persei given in the *Harvard Annals*, **48**, 89. In our table quantities deduced by interpolation are printed in brackets. The contents of the table will be easily understood from the headings of the various columns, with the exceptions of the last two columns, which perhaps require a word of explanation.

TABLE A.

Maxima and Minima, Nova Aquilæ.

Date. Max.	Date. Min.	Magnitude. Max.	Magnitude. Min.	Interval in Days. Max. to Max.	Interval in Days. Min. to Min.	Interval in Days. Max. to Min.	Interval in Days. Min. to Max.	Range of Mag. Max. to Min.	Range of Mag. Min. to Max.	Range of Mag. (corrected). Max. to Min.	Range of Mag. (corrected). Min. to Max.
1918.	1918.										
...	June 29	...	3·79	...	(11)	...	4	...	0·61	...	0·69
July 3	July (10)	3·18	3·75	13	(12)	(7)	(6)	0·57	0·15	0·42	0·28
16	22	3·60	(4·36)	11	12	6	5	(0·76)	(0·53)	(0·64)	(0·64)
27	Aug. 3	3·83	(4·38)	12	11	7	5	0·55	(0·52)	0·40	(0·62)
Aug. 8	14	3·86	4·67	10	9	6	4	0·81	0·25	0·68	0·33
18	23	4·42	4·82	(9)	10	5	(4)	0·40	...	0·29	...
(27)	Sept. 2	...	5·08	(11)	...	(6)	...	...	0·42	...	0·52
Sept. 7	...	4·66	...	...	...	...	...	...	...	..	...
Means		3·9	4·4	11·0	10·8	6·2	4·7	0·62	0·41	0·49	0·51

It will be seen that there is a well-marked periodicity of about 11 days, the periodic range in magnitude from maximum to minimum being 0·62 mag., and from minimum to maximum 0·41 mag. The difference between these two ranges is, of course, due to the progressive diminution of brightness which was going on at the same time. This progressive change is found to take place at the mean rate of 0·022 mag. per diem, and, correcting the figures in the 9th and 10th columns for this effect, we obtain those exhibited in the last two columns, the difference between the two resulting mean values being practically negligible.

We thus deduce a well-marked variation in brightness, with a range of 0·5 mag., taking place in a period of about 11 days.

The accompanying diagram (Plate 1) represents the magnitudes of Nova Aquilæ (1918) and of Nova Persei (1901). For con-

venience it is divided into two parts, placed one above the other, and in each case the scale of magnitudes, given in the right- and left-hand margins, refer equally to the two stars. The dates given along the upper margin of both sections refer to the observations of Nova Aquilæ, whilst those along the lower margin refer to Nova Persei. For purposes of comparison, the curves are placed so that the dates of greatest brilliance in the two cases coincide, viz. 1918 June 9 for Nova Aquilæ, and 1901 February 23 for Nova Persei. According to Professor Barnard, as seen in America, Nova Aquilæ increased in magnitude on June 9 to $-1\cdot4$, nearly equalling Sirius in brilliance, and thus exceeding by a whole magnitude the mean of the values obtained by European observers earlier on that night. The maximum magnitude of Nova Persei was 0·0 on 1901 February 23, but the next night it had fallen to 0·57 (*H.A.*, **48**, 84).

It will be seen from the diagram that the curves of the two Novæ run on the whole nearly parallel, with a general tendency to diverge slightly towards the end.

TABLE B.

Three Stages in Decline of Nova Aquilæ 1918, *and Nova Persei* 1901.
Average Rates of Decrease in Magnitude.

Star.	Date.	Days from Greatest Brilliance.	Observed Magnitude	Date.	Days from Greatest Brilliance.	Observed Magnitude.	Interval in Days.	Decrease of Mag. in Interval.	Rate of Decrease per Diem.
Nova Aquilæ	1918 June 11	2	0·50	June 26	17	3·39	15	2·89	0·193
,, Persei	1901 Feb. 25	2	0·90	Mar. 12	17	3·87	15	2·97	0·198
Nova Aquilæ	1918 June 26	17	3·39	Sept. 3	86	4·95	69	1·56	0·022
,, Persei	1901 Mar. 12	17	3·87	May 20	86	5·67	69	1·80	0·026
Nova Aquilæ	1918 Sept. 3	86	4·95	Dec. 3	177	5·26	91	0·31	0·003
,, Persei	1901 May 20	86	5·67	Aug. 20	178	6·46	92	0·79	0·009

With regard to Nova Aquilæ, the light curve shows at least three distinct phases (see Table B).

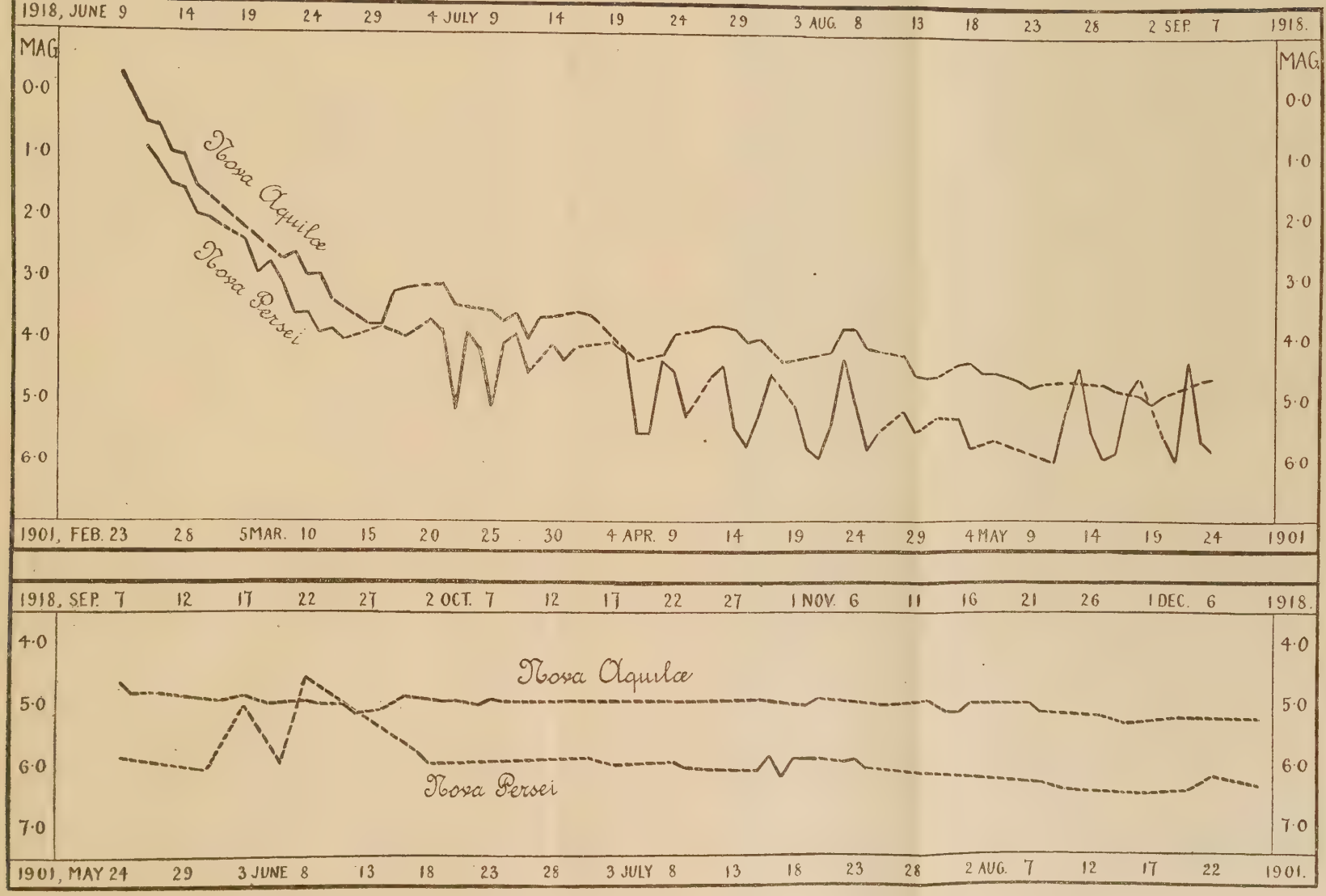
(1) A rapid fall from June 11 till about June 26—a period of 15 days—at an average rate of 0·193 mag. per diem.

(2) A series of oscillations of brightness with a mean period of 11 days from June 26 to September 3 (69 days *), with an average amplitude of 0·5 mag.

(3) Except for a few slight variations, nearly stationary from September 3 onwards, the decline amounting only to about a quarter of a magnitude in 98 days.

* It is interesting to note that the light-curve of Nova Geminorum, 1912 (see *H.A.*, 76, 242), shows, for that star, oscillations of varying intensity which lasted also for about 69 days, after which it remained nearly stationary for more than 8 months.

Radcliffe Magnitudes of Nova Aquilæ, 1918 and Nova Persei, 1901.



Similarly there were three stages in the light-changes of Nova Persei, 1901 (see Table B).

(1) A rapid fall in 15 days from February 25 to March 12 at the rate of 0·198 mag. per diem.
(2) From March 20 the great oscillations began, but in this case they continued for nearly 100 days, until the middle or end of June.*
(3) A quiescent stage from July 1 onwards, slowly declining in brightness.

In Table I. below are given a number for reference, the names of the comparison stars used, their positions for 1918·0, and their magnitudes taken from the *Revised Harvard Photometry*, on which our estimates are based.

Table II. contains the means of each observer's separate comparisons and the general mean for each evening. The results in the fifth and sixth columns are both corrected for atmospheric absorption by means of the table given in the *H.A.*, 14, 66.

TABLE I.

List of Stars used for Comparison with Nova Aquilæ.

Ref. No.	Name of Star.	R.A. 1918·0.	Decl. 1918·0.	Magnitude (H.R.).
		h m	° ′	
1	Vega	18 34	+38 42	0·14
2	Arcturus	14 12	+19 37	0·24
3	Altair	19 47	+ 8 39	0·89
4	Spica	13 21	−10 44	1·21
5	Antares	16 24	−26 15	1·22
6	α Cygni	20 39	+44 59	1·33
7	η Ursæ Majoris	13 44	49 43	1·91
8	α Ophiuchi	17 31	12 37	2·14
9	γ Cygni	20 19	40 0	2·32
10	ε Cygni	20 43	+33 40	2·64
11	β Scorpii (combined light)	16 1	−19 35	2·76
12	γ Aquilæ	19 42	+10 25	2·80
13	β Herculis	16 27	21 40	2·81
14	β Ophiuchi	17 39	4 36	2·94
15	δ Cygni	19 42	44 56	2·97
16	ζ Herculis	16 38	31 45	3·00
17	ζ Aquilæ	19 2	13 44	3·02
18	β Cygni (combined light)	19 27	27 47	3·10
19	δ Herculis	17 12	+24 56	3·16

* The first of these oscillations really occurred between March 18 and 20 (see *H.A.*, **48**, 89), but was not observed at Oxford owing to clouds.

TABLE I.—*continued.*

Ref. No.	Name of Star.	R.A. 1918·0.	Decl. 1918·0.	Magnitude (H.R.).
		h m	° ′	
20	η Serpentis	18 17	− 2 55	3·42
21	κ Ophiuchi	16 54	+ 9 30	3·42
22	δ Aquilæ	19 21	2 57	3·44
23	λ Aquilæ	19 2	− 5 0	3·55
24	γ Ophiuchi	17 44	2 44	3·74
25	γ Herculis	16 18	19 21	3·79
26	β Aquilæ	19 51	6 12	3·90
27	ϵ Herculis	16 57	31 3	3·92
28	67 Ophiuchi	17 57	2 56	3·92
29	1 Aquilæ (α Scuti)	18 31	− 8 18	4·06
30	70 Ophiuchi	18 1	+ 2 31	4·07
31	θ Serpentis (combined light)	18 52	4 5	4·10
32	12 (i) Aquilæ	18 57	− 5 51	4·15
33	ϵ Aquilæ	18 56	+14 57	4·21
34	ι Ophiuchi	16 50	10 18	4·29
35	68 Ophiuchi	17 58	+ 1 18	4·44
36	6 Aquilæ (β Scuti)	18 43	− 4 50	4·47
37	66 Ophiuchi	17 56	4 22	4·81
38	4 Aquilæ	18 41	+ 1 58	5·04
39	9 Aquilæ	18 53	− 5 57	5·04
40	5 Aquilæ	18 42	1 3	5·68
41	e Serpentis	18 33	− 0 23	5·80

The position of Nova Aquilæ is R.A. $18^h\ 45^m$, Decl. $+0°\ 30'$ (1918·0).

TABLE II.

Means of Estimations of Magnitude of Nova Aquilæ.

G.M.T. 1918.	h m	Obsr.	Instrument Used.	Comparison Stars.	Mean Magnitude.	Adopted Magnitude for the Night.
June 9	10 10	H.B.	*n*	1, 3	−0·33	−0·33
10	9 40	H.B.	*n*	3, 1	+0·05	+0·05
11	10 0	R.	*n*	4, 1, 3	0·49	
	10 30	R.	*n*	1, 3, 4	0·49	0·50
	10 30	A.A.R.	*n*	3, 1, 3, 2	0·51	
12	9 45	A.A.R.	*n*	3, 1	0·47	0·56
	9 50	R.	*n*	3, 1	0·64	
13	9 15	R.	*n*	3	1·15	0·98
	9 30	A.A.R.	*n*	3	0·82	

TABLE II.—*continued.*

G.M.T. 1918.	h	m	Obsr.	Instrument Used.	Comparison Stars.	Mean Magnitude.	Adopted Magnitude for the Night.
June 14	10	20	H.B.	*n*	3	0·95	1·02
	12	0	R.	*n*	3, 3, 6	1·05	
15	9	40	A.A.R.	*n*	6, 9, 4, 7, 3, 12, 5, 11	1·47	1·52
	10	15	R.	*n*	3, 12, 6, 4, 8	1·58	
	10	15	H.B.	*n*	3, 8	1·48	
16	10	15	R.	*n*	6, 8, 3, 12	1·70	1·70
22	10	15	A.A.R.	*n*	12, 17, 18	2·78	2·73
	11	10	R.	*n*	14, 12, 8, 15, 10, 18	2·68	
23	9	45	R.	*n*	12, 14, 8, 20, 10, 15	2·62	2·62
24	10	5	A.A.R.	*f*	12, 26, 14, 24, 14, 21, 13, 25, 19, 16, 27	3·07	3·00
	10	30	R.	*n*	14, 12, 20	2·94	
25	10	20	R.	*n*	12, 14, 20, 17	2·98	2·98
26	10	20	R.	*m*	22, 23, 20, 17, 33, 14, 24	3·35	3·39
	10	40	R.	*m*	22, 23, 20, 12	3·38	
	11	20	R.	*n*	22, 20, 23	3·44	
29	10	25	R.	*m*	20, 23, 32, 26, 22, 31, 24	3·79	3·79
30	10	15	R.	*m*	20, 23, 32, 26, 22, 31, 24	3·79	3·79
July 1	10	0	R.	*m*	20, 22, 12, 26	3·31	3·27
	10	30	R.	*n*	20, 22	3·24	
2	10	38	A.A.R.	*n*	12, 20, 14, 24, 17, 20, 21, 34, 17, 22	3·28	3·21
	10	45	R.	*n*	14, 20, 17, 22, 20, 22, 17, 14, 24, 12, 22	3·14	
3	10	30	R.	*n*	17, 22, 20, 14, 20, 12, 22	3·13	3·18
	11	3	A.A.R.	*n*	17, 20, 17, 22, 14, 24, 17, 23	3·23	
5	10	15	R.	*m* & *n*	20, 22, 12, 22	3·15	3·15
	10	30	A.A.R.	*n*	17	(2·94)	
6	10	20	R.	*m*	20, 22	3·44	3·48
	10	55	A.A.R.	*n*	20, 22, 17, 23, 14, 24, 12, 23	3·52	
9	9	55	R.	*n*	22, 23, 20	3·57	3·58
	10	5	R.	*m*	22, 23, 20	3·56	
	10	50	A.A.R.	*n*	22, 31, 20, 24, 17, 26, 23, 31	3·62	
10	9	53	R.	*m*	20, 22, 23	3·65	3·75
	10	46	A.A.R.	*n*	20, 31, 23, 29, 22, 24, 20, 26	3·85	
11	9	48	R.	*n*	22, 26, 20, 24	3·64	3·64
12	10	10	R.	*m*	31, 24, 26, 30	3·99	4·05
	10	57	A.A.R.	*n*	24, 29, 20, 36, 22, 36	4·10	

TABLE II.—*continued.*

G.M.T.		Obsr.	Instrument Used.	Comparison Stars.	Mean Magnitude.	Adopted Magnitude for the Night.
1918.	h m					
July 13	10 55	A.A.R.	*n*	31	(4·07)	3·68
	11 5	R.	*m*	22, 26, 24, 28, 30	3·68	
14	9 55	R.	*m*	20, 22, 24, 26	3·67	3·67
16	9 58	R.	*n*	20, 22, 26, 24	3·60	3·60
17	9 20	R.	*f*	20, 22, 26	3·64	3·64
18	9 45	R.	*m*	22, 26, 23, 31, 24, 30	3·81	3·81
21	10 0	R.	*m*	32, 39, 26, 30, 37, 31, 38	4·40	4·40
23	9 30	R.	*m*	26, 31, 38	4·31	4·31
24	9 45	R.	*m*	22, 31, 26, 31	3·97	3·97
26	10 12	R.	*m*	31, 22, 26	3·90	3·90
27	9 40	R.	*m*	31, 26, 22	3·83	3·83
28	10 10	R.	*m*	31, 26, 22	3·84	3·84
29	9 35	R.	*m*	24, 20, 22, 31, 26	3·80	3·89
	10 5	A.A.R.	*n* & *f*	20, 31, 23, 29	3·97	
30	9 30	R.	*m*	31, 26	4·09	4·09
31	10 0	R.	*b*	26, 24, 31, 30	4·03	4·03
Aug. 2	9 25	R.	*b*	26, 31, 38	4·42	4·42
6	9 2	R.	*b*	31, 38, 26	(4·45)	4·25
	11 0	A.A.R.	*n*	22, 31	(3·86)	
7	10 10	R.	*b*	31, 26	3·97	3·86
	11 8	A.A.R.	*n*	22, 31, 23, 29, 20, 26	3·74	
8	9 45	R.	*b*	31, 20, 26	3·86	3·86
9	9 10	R.	*b*	26, 31	4·22	4·18
	9 30	R.	*b*	26, 31, 30	4·10	
	10 3	A.A.R.	*n* & *f*	22, 31, 29, 26, 31, 32, 39	4·22	
10	8 55	R.	*b*	26, 31, 30, 35	4·12	4·22
	10 10	A.A.R.	*n*	22, 31, 32, 39, 30	4·32	
12	9 10	R.	*b*	31, 38, 30, 35	4·31	4·31
13	9 5	R.	*b*	31, 38, 32, 39, 35, 37	4·73	4·63
	11 17	A.A.R.	*f*	31, 38, 29, 38, 32, 39, 31, 38	4·53	
14	8 35	R.	*b*	31, 38, 35, 37, 32, 39	4·63	4·67
	10 0	R.	*b*	31, 38, 35, 37, 32, 39	4·71	
15	8 45	R.	*b*	38, 31, 39, 32, 37	4·91	4·65
	9 48	A.A.R.	*f*	38, 31, 39, 32	4·38	
17	8 40	R.	*b*	31, 38, 35, 30	4·39	4·45
	9 20	R.	*b*	31, 38, 35	4·52	
18	8 30	R.	*b*	35, 30, 31, 38, 32, 39	4·50	4·42
	10 7	A.A.R.	*f*	38, 31, 39, 32, 38, 23, 39, 31	4·34	

TABLE II.—*continued.*

1918.	G.M.T. h	m	Obsr.	Instrument Used.	Comparison Stars.	Mean Magnitude.	Adopted Magnitude for the Night.
Aug. 19	9	40	R.	*b*	31, 38, 35, 39, 32	4·59	4·59
20	9	5	R.	*b*	39, 32, 38, 31, 37, 35	4·72	4·58
	9	50	A.A.R.	*f*	38, 31, 39, 32, 38, 23, 38, 32	4·43	
21	8	50	R.	*b*	39, 32, 37, 35, 38, 31	4·76	4·65
	10	48	A.A.R.	*f*	38, 31, 39, 32	4·53	
22	8	25	R.	*b*	38, 31, 39, 32, 37, 35	4·72	4·72
23	10	10	R.	*b*	39, 37, 38, 31	4·98	4·82
	10	36	A.A.R.	*f*	38, 31, 39, 32	4·66	
24	8	20	R.	*b*	37, 38, 31, 39, 32	4·96	4·77
	9	57	A.A.R.	*f*	38, 31, 39, 32	4·57	
26	7	55	R.	*b*	38, 31	4·73	4·73
29	8	45	R.	*b*	38, 31, 39, 32, 37	4·77	4·77
30	9	50	R.	*b*	38, 31, 39, 32, 37	4·88	4·88
Sept. 1	7	55	R.	*b*	38, 31	4·93	4·95
	9	10	R.	*b*	38, 31, 39, 32, 37, 38	4·97	
2	8	0	R.	*b*	38, 39	5·07	5·08
	8	45	R.	*b*	38, 39, 37, 40	5·08	
3	10	0	R.	*b*	38, 31, 39, 32, 37, 38	4·95	4·95
6	7	45	R.	*b*	38, 31, 39, 32, 37, 35	4·72	4·71
	8	5	R.	*f*	38, 31, 39, 32, 35, 37	4·70	
7	8	10	R.	*m*	37, 35, 38, 31, 39, 32	4·66	4·66
8	8	5	R.	*m*	37, 38, 31, 39, 32	4·85	4·85
10	8	30	R.	*m*	37, 38, 31	4·84	4·84
12	7	40	R.	*m*	37, 38, 38, 31, 39, 32	4·82	4·90
	10	10	A.A.R.	*f*	38, 31, 39, 32	4·97	
15	9	30	R.	*m*	38, 31	4·96	4·96
	9	50	A.A.R.	*f*	38, 31, 39, 32	4·95	
17	7	30	R.	*m*	38, 31	4·89	4·89
19	7	30	R.	*m*	38, 37, 38, 31, 39, 32	4·93	5·01
	10	0	A.A.R.	*f*	38, 39, 32	5·09	
22	8	30	R.	*m*	38, 31, 39, 32	4·96	4·96
23	7	0	R.	*m*	38, 31, 37, 38, 39, 32	4·96	5·01
	8	20	R.	*m*	38, 31, 37, 38, 39, 32	4·95	
	10	3	A.A.R.	*f*	38, 39, 32	5·12	
25	8	30	R.	*m*	38, 31, 38, 37, 39, 32	5·01	5·02
	9	35	A.A.R.	*f*	38, 31, 39, 32	5·03	
26	9	45	R.	*m*	38, 31, 38, 37, 39, 32	5·04	5·15
	9	52	A.A.R.	*f*	38, 31, 39, 32, 40, 37	5·27	

TABLE II.—*continued.*

G.M.T. 1918.	h	m	Obsr.	Instrument Used.	Comparison Stars.	Mean Magnitude.	Adopted Magnitude for the Night.
Sept. 28	8	0	R.	*m*	38, 31, 38, 37, 39, 32	5·00	5·12
	9	20	A.A.R.	*f*	38, 31, 39, 32, 40, 37	5·25	
30	7	10	R.	*m*	37, 38, 39, 32, 38, 31	4·90	4·90
Oct. 3	8	45	R.	*m*	38, 31	4·91	4·97
	9	45	R.	*m*	38, 31, 37, 38, 39, 32	5·00	
4	7	5	R.	*m*	38, 31, 38, 37, 39, 32	4·96	4·96
6	8	30	R.	*m*	38, 31, 39, 32, 37, 38	5·03	5·03
7	7	10	R.	*m*	38, 37, 38, 31, 39, 32	4·95	4·95
8	7	5	R.	*m*	38, 31, 39, 32, 38, 37	4·98	4·98
13	8	30	R.	*m*	38, 31, 37, 38	4·97	4·97
22	6	45	R.	*m*	38, 31, 39, 32	4·97	4·97
29	7	10	R.	*m*	38, 31	4·94	4·94
Nov. 2	6	5	R.	*m*	38, 31, 39	5·04	5·04
3	8	28	R.	*m*	38, 31	4·94	4·94
8	6	20	R.	*m*	38, 31, 39, 38, 37	5·03	5·03
9	7	30	R.	*m*	38, 31	5·03	(5·03)
12	6	20	R.	*m*	38, 31	4·97	4·96
	7	20	R.	*f*	38, 31	4·95	
14	6	42	A.A.R.	*f*	40, 38, 41	5·31	5·16
	7	0	R.	*f*	38	5·01	
15	5	58	A.A.R.	*f*	38, 40, 38, 41	5·31	5·17
	6	20	R.	*f*	38	5·03	
16	6	5	R.	*f*	38	5·02	5·02
21	6	8	R.	*m*	38	5·02	5·02
22	5	35	R.	*m*	38, 40	5·09	5·16
	6	0	R.	*f*	38, 40	5·24	
27	5	40	R.	*m*	38, 40	5·24	5·24
29	5	50	R.	*m*	38, 40	5·37	5·37
Dec. 3	5	20	R.	*m*	38	5·34	5·26
	5	40	R.	*m*	38, 40	5·15	
	6	15	R.	*f*	38, 40	5·34	
10	5	45	R.	*m*	38, 40	5·27	5·27
	6	10	R.	*f*	38, 40	5·28	

Observers' Notes.

1918.

June 9. For H.B.'s notes see p. 109.

10. Observations made in bright sky (H.B.).

11. The brilliance and lustre of the Nova are remarkable. In character, the image as seen by the naked eye and in a good field-glass resembles those of Altair and Vega, but is much more sparkling than Arcturus. The comparison of the Nova with Arcturus for magnitude was difficult on account of the reddish colour of the latter (A.A.R.).

15. The Nova is slightly reddish and very similar in colour to Arcturus (A.A.R.). Nova dull and suspected of reddish colour (R.). In a hazy sky (H.B.).

16. Nova fainter than as observed last night. Clouds (H.B.).

22. Colour reddish, but not so red as Arcturus. In the Barclay 10-inch refractor, power 85, at 11^h G.M.T., the brilliance of the red fringe of the infra-focal image was very remarkable, and exhibited a strong contrast with the fainter red in the image of γ Aquilæ at the same focal adjustment. The focal setting for the Nova was about $\frac{1}{18}$th of an inch longer than for a neighbouring white star in the field (A.A.R.). Focussed power 85 on a faint star near the Nova: the image of the Nova was then seen to be out of focus, having a yellow nucleus with a ruby fringe. The focus for the Nova is slightly the longer (R.).

23. Moonlight and twilight (R.).

24. Nova redder than either γ or β Aquilæ (A.A.R.). Moonlight, twilight, and haze: observations very difficult (R.).

25. Observations difficult owing to twilight and moonlight (R).

26. Nova reddish (R.).

July 1. Nova has brightened: it is reddish (R.).

2. Nova distinctly red in colour (A.A.R.).

3. Nova distinctly red, both to the naked eye and with field-glasses (A.A.R.). At 8.45 G.M.T., with Barclay refractor, power 85, Nova, at ordinary focus, yellow with bright red fringe: at the longer focus, nucleus ruby red and well defined (R.).

5. Nova appears equal in brightness to ζ Aquilæ, but observations difficult through shifting clouds, and accuracy unattainable (A.A.R.).

6. The Nova still appears ruddy to the naked eye, but not distinctly red, as on July 3. In field-glasses, the redness is quite distinct, the new star appearing redder than any of those with which it was compared to-night (A.A.R.). The Nova is a little fainter to-night and its colour reddish (R.).

9. Image of Nova in field-glasses very red. Distinctly ruddy to naked eye (A.A.R.).

10. Nova through field-glasses appeared very red at 9.15 G.M.T., more so than Arcturus. At 10^h 59^m G.M.T. Nova appeared a dull red to the naked eye, but very red through field-glasses (A.A.R.). The reddish colour of the Nova renders comparison with the other stars for magnitudes difficult (R.).

12. Image of Nova in field-glasses ruddy, but not so red as on the 10th (A.A.R.). Nova dull (R.).

13. Nova appears equal to θ Serpentis. Much cloud prevalent, but both stars seemed clear of clouds at the time of observation (A.A.R.). Contrast in colours of comparison stars and Nova much less marked to-night (R.).

14. Colour of the Nova is not pronounced to-night (R.).

17. Nova ruddy (R.).

23. Wisps of cirrus coming up prevented further observations (R.).

26. At 9^h 15^m G.M.T., with the Barclay refractor, power 85, the red fringe around Nova still conspicuous (R.).

1918.

July 28. Sky misty and frequently cloudy (R.).

29. Naked-eye observations confirmed by observation with field-glasses. With the glasses the Nova seems rather redder than η Serpentis or λ Aquilæ. But the Nova is certainly not so red as when last seen well, *i.e.* on July 12 (A.A.R.).

31. $9^h\ 30^m$ G.M.T., Barclay refractor, power 85. At ordinary star-focus the image of Nova still shows a red fringe (R.).

Aug. 6. Observed in a short break in clouds (A.A.R.). Sky became overcast immediately after observations (R.).

7. Nova appears a little brighter to-night. Image of Nova in field-glasses still distinctly reddish (A.A.R.).

8. Difficult observations; cloudy (R.).

9. Image of Nova is very slightly reddish with field-glasses. Comparisons for magnitude were made both with field-glasses and naked eye (A.A.R.).

13. Image of Nova in field-glasses very slightly reddish (A.A.R.).

15. Both pairs of observations good in clear sky. But thin cloud extending upwards from S.W. covered the region before another comparison could be made (A.A.R.).

18. Moonlight very bright. Image in glasses distinctly reddish (A.A.R.).

20. No redness noticeable in image of Nova in field-glasses (A.A.R.).

21. Very bright moonlight: observations difficult (A.A.R.). Moonlit sky; slight haze (R.).

23. Image of Nova in field-glasses white; no trace of red (A.A.R.) The image of the Nova seems duller, although larger, than the images of 4 Aquilæ and 66 Ophiuchi (R.).

Sept. 12. Very little if any trace of colour in Nova. Hardly so white as θ Serpentis, 4 Aquilæ or 9 Aquilæ, but distinctly less red than 12 Aquilæ. Sky very clear. To the naked eye 4 Aquilæ and Nova appear almost exactly equal (A.A.R.).

26. Sky quite clear. Colour of Nova is slightly yellow in field-glasses (A.A.R.).

Oct. 29. Clouds passing (R.).

Nov. 9. Observation rather doubtful; clouds passing (R.).

14. Image of Nova in field-glasses not so white as (*i.e.* more orange than) that of 4 Aquilæ (A.A.R.). Fluctuating slightly above and below 4 Aquilæ in brightness, but sky misty (R.).

15. Clear sky. Bright moonlight (A.A.R.). Image of Nova again fluctuated in brightness within small limits, rendering comparison difficult (R.).

27. 6^h–7^h G.M.T., in the Barclay 10-inch refractor, power 85, the Nova was colourless at the usual focus; but its extra-focal image was well defined and bright red, with a broad marginal fringe of blue colour. A distinctly orange-coloured star was found in the vicinity (B.D. $+4°$ 3884) with its extra-focal image very similar in colour to that of the Nova, but with no definite tint in its fringe. This star is described in the Radcliffe 1900 Catalogue, No. 1419, as "orange red" (R.).

The observers were:—

Dr. A. A. Rambaut,	indicated by A.A.R.
Mr. W. H. Robinson,	,, ,, R.
Mr. H. G. Scott Barrett,	,, ,, H.B.

Radcliffe Observatory, Oxford:
1918 *December* 11.

The Earlier Spectrum of Nova Aquilæ, 1918.

By the Rev. A. L. Cortie, S.J. (Plates 2, 3.)

Through the kindness of the Astronomer Royal, a telegram announcing the discovery of Nova Aquilæ was received on the morning of June 10. The night being on the whole fine, it was possible to begin observations at once. To the naked eye the star appeared brighter than Altair, but less bright than Vega. Two photographs of the spectrum of the star were obtained that night, and one on the following night. The present paper deals mainly with these spectra.

The instrument employed was the Thorp prismatic camera, having an objective prism of 22·5° angle, and 3 inches aperture, made by the late Mr. T. Thorp of Manchester, and a 3-inch achromatic lens made by Cooke of York. The adjustments of the instrument were fully described by Father Sidgreaves in a paper on the spectrum of Nova Persei,* 1901, and the same adjustments were maintained in taking the photographs of the spectra here described, with the exception that the slew of the camera was slightly altered, giving a longer extension of the spectrum, especially in the violet. In the former setting the length of the spectrum from H_β to H_v was 21 mm.; in the present instance the length was 22·8 mm. The spectra, however, though in very good focus, lack the excellence of focus attained by those taken by Father Sidgreaves. The plates used were Ilford Monarch rapid plates, and the developer Rytol.

Other observers have already remarked on the very rapid scintillations of the star. The same phenomenon was strikingly evident to the writer, and was independent of any possible changes in atmospheric conditions. Professor Newall has described his observations of the spectrum of the star by a direct vision prism without any telescope,† and the extraordinary brightness of the red radiation in the spectrum of the Nova was projected on the sky.

On June 15 the spectrum of the Nova was similarly compared with that of Altair, by means of a transmission grating. While the spectrum of Altair so observed was continuous, with a maximum of brilliancy in the green, that of the Nova was almost entirely confined to the red. This is corroborative evidence as to the extraordinary relative brilliancy of the red hydrogen radiation.

Two plates of the spectrum of the Nova were obtained on June 10, the first exposure being made from 11.0 to 11.30 p.m. G.M.T.; and the second from 11.35 to 12.15 p.m. G.M.T. The magnitude of the star, according to the curve published in the *Journal of the British Astronomical Association* for June 1918, constructed by Mr. C. L. Brook, was about −0·5. The spectrum extends from λ5180 to H_χ, λ3670, in the ultra-violet.

* *Monthly Notices R.A.S.*, 62, 137.
† *Ibid.*, 78, 577, 578.

The extension into the ultra-violet, the spectrum embracing all the hydrogen line series from H_β to H_χ, is noteworthy. The spectrum consists of a series of dark lines, which closely match the spectrum lines of α Cygni, which is classed as A2F peculiar in the Draper Catalogue, and of a series of bright bands, which, as in all Novæ, adjoin the corresponding dark lines on their less refrangible edges. The bright bands became more prominent on June 11 and succeeding dates, when the dark line spectrum was disappearing. The more prominent bright bands on June 10 were those adjoining the hydrogen lines, especially H_β, H_γ, H_δ, and H_ϵ, and those less refrangible about λ5019 and λ4924. There was also a very prominent, narrow bright band between H and K, at about λ3950.

There were two bright bands about the position λ4640, even on this early date in the life-history of the star. They were separated by a dark space. Although they grew greatly in intensity as the star waned in magnitude, they maintained this character, as a double band with dark central absorption, until at least June 30. The bright bands adjoining H_γ, H_δ, and H_ϵ had a very complicated structure, as a reference to the appended table will show. The H_β bright band, which extended from λ4862 to λ4918, had a brighter central portion. The mean width of the four bright bands H_β, H_γ, H_δ, H_ϵ was 55 A.U., and this width they maintained, unaltered apparently, until at least August 13. The permanence of the width of the bright hydrogen bands in new stars is a remarkable phenomenon. It would indicate the cause of the widening to be due rather to pressure than to line-of-sight displacement.

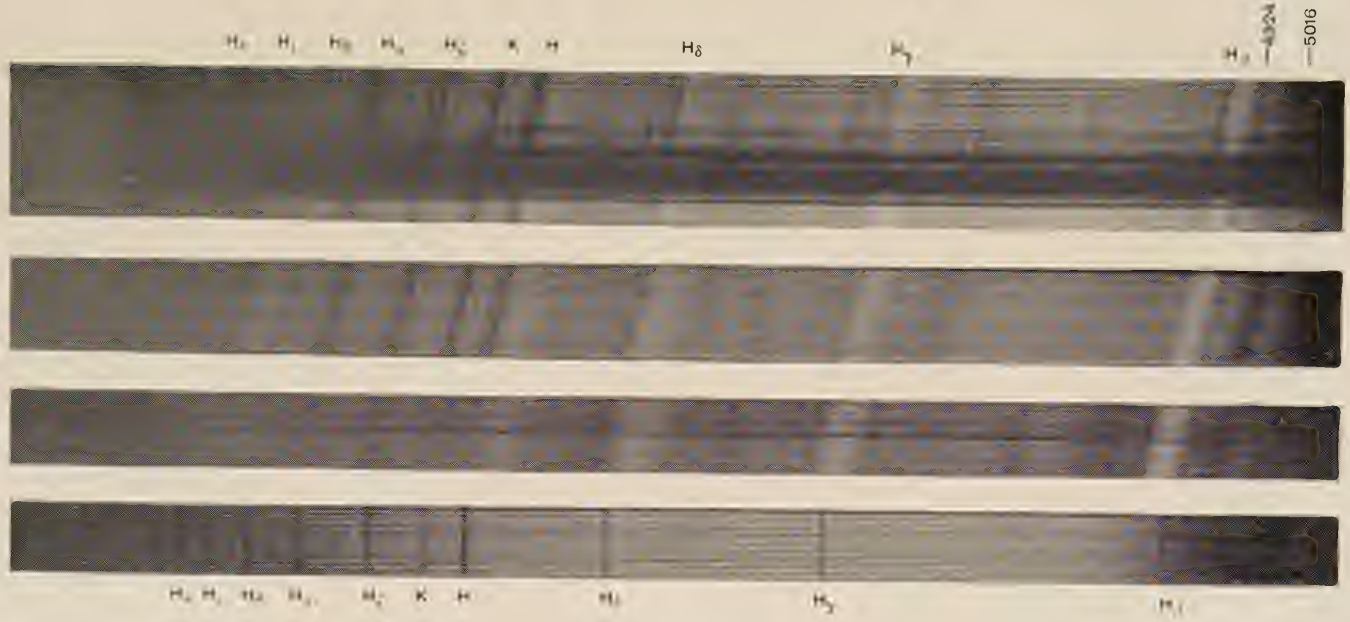
The most striking appearance in the dark line spectrum of the Nova was the double set of displaced hydrogen lines, as usual the displacement being to the violet. The first set, of less displaced lines, was sharper than the second set of more displaced lines, which was hazy and seemed to be itself made up of double lines. This feature was in evidence until at least June 15.

Unless a comparison spectrum is impressed on the plate, it is not possible to get very accurate determinations of the radial velocities. However, several determinations of the radial velocities of the two sets of hydrogen lines have been made by the method due to Orbinski,* which is facilitated by the irrationality of dispersion in the case of a prismatic spectrum. Although several of the results obtained are discordant and puzzling, yet there seems to be sufficient evidence for velocities of about 900 km./sec. for the first set of hydrogen lines, and of 1700 km./sec. for the second set. The latter result is the better of the two. It is intended, however, to return to this subject when the other plates have been measured.

The wave-lengths of the dark lines, and of the bright bands and lines, given in the table were obtained in the following manner:— It was found that the more refrangible edges of the bright bands

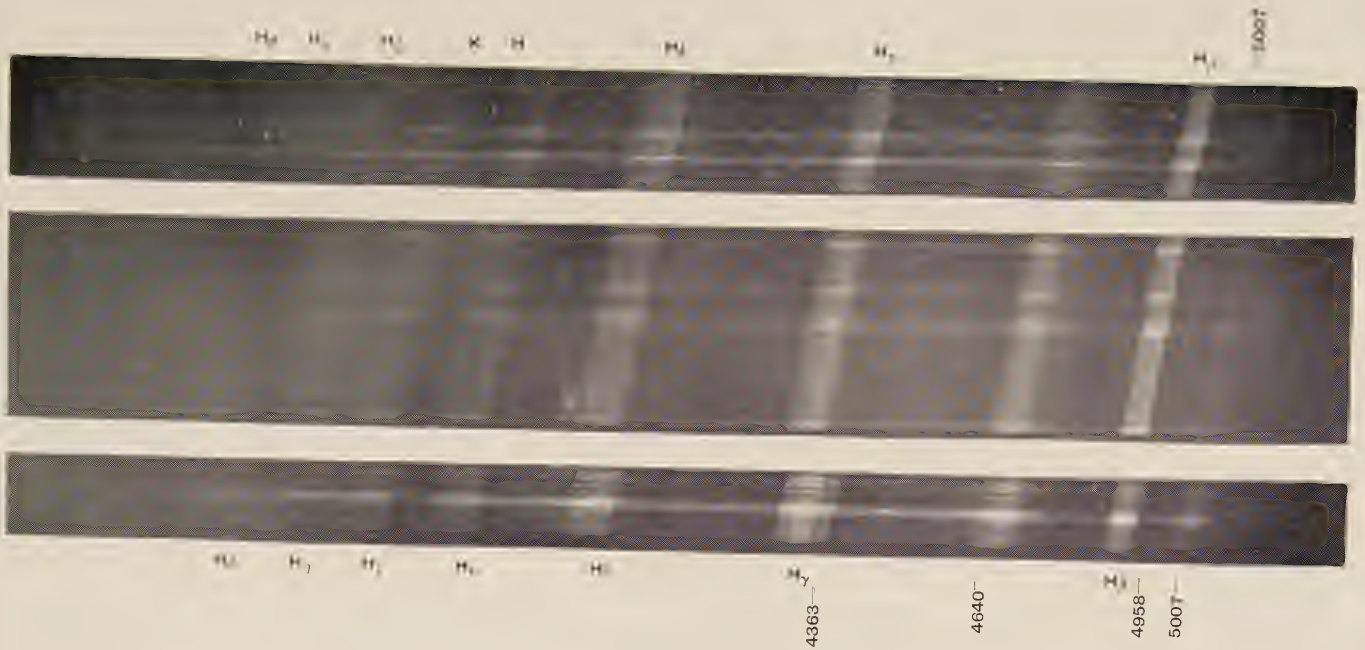
* *The Observatory*, August 1895, p. 303.

Progressive Spectra of Nova Aquilæ, 1918. I.



1. June 10, 11.35 to 12.15 p.m.
2. June 11, 10.45 to 11.25 p.m.
3. June 15, 10.35 to 11.5 p.m.
4. α Cygni.

Progressive Spectra of Nova Aquilæ, 1918. II.



1 June 24, 11.50 to 12.50 p.m. 2. June 30, 10.45 to 12 p.m.
3. July 29, 10.26 to 11.5 p.m.

at H_β, H_γ, H_δ were in exact agreement with the micrometer readings for these lines, which were the means of values from many settings derived from the stars Procyon, Sirius, α Coronæ, and γ Cassiopeiæ. Accordingly, a graph of the Hartmann-Cornu formula, according to the method of Dr. Henroteau, was constructed with these three readings as fiducial points, which was employed between the limits H_β and H_δ, and by extrapolation to H_ϵ.

Furthermore, an excellent spectrum of α Cygni, which had been obtained some years ago by Father Sidgreaves with a different slew of the camera, and therefore had different values in micrometer readings for the differences in linear dispersion between the hydrogen lines, was carefully measured. From the resulting micrometer readings the wave-lengths of the principal lines in this star were obtained by means of a curve which had been constructed for the slew of the camera employed. These values of the wave-lengths of the lines in α Cygni formed a valuable check on the values for the corresponding dark lines in the Nova, which had been independently obtained. They are set down in the fifth column of the table, with their intensities in the sixth column. The agreement between the values of the wave-lengths of the dark lines in the Nova, and the corresponding dark lines in α Cygni, is sufficiently close to warrant the correctness of the former within one or two Angström units.

The wave-lengths of the dark lines in α Cygni also serve the purpose of the identification of the corresponding lines in the Nova. They also show the close similarity between the dark-line spectra in the two stars.

For the wave-lengths of the lines and bands in the Nova beyond H_δ, a curve was constructed, using as fiducial points the series of readings of the wave-lengths of the hydrogen lines from H_δ to $H_\circ$. And in this position of the spectrum the change in the wave-lengths of the dark lines, other than the hydrogen lines, and of the bright bands, due to displacement, was corrected by actual comparison with the corresponding lines in the spectrum of α Cygni. This was facilitated by the employment of six-fold paper enlargements of the spectra of the two stars.

As the edges of the bright bands are in most cases bounded by dark lines, it may be assumed that the wave-lengths given for them, in column three of the table, are also correct. In column seven of the table, the wave-lengths of what were judged to be corresponding lines in the chromospheric spectrum are taken from the Astronomer Royal's Memoir on the spectra obtained at total solar eclipses.* Enhanced chromospheric lines are indicated by an asterisk. The considerable number of such lines which are found in the spectrum of the Nova indicates how closely its earlier spectrum approximates to the solar chromospheric spectrum.

In the table the positions of the double set of displaced hydrogen lines are given with their displaced wave-lengths, as

* *Memoirs, R.A.S.*, Appendix to vol. 57.

determined from the two curves. In the ultra-violet the displaced hydrogen lines of the second, more refrangible set sometimes form blends with the less displaced lines of the first set which follow them. Moreover, some of the other lines, not due to hydrogen, coalesce in these blends, giving the appearance of broad dark lines or bands. It is somewhat difficult to unravel such blends, and for this purpose the enlarged comparison spectrum of α Cygni has been very helpful.

In measuring the spectrum of α Cygni it was noted that many of the lines have a diffused, ill-defined, and hazy appearance, especially in the region between H_δ and H_ϵ. This feature exactly corresponds with many of the dark lines in the spectrum of the Nova, which is another point of similarity between the two spectra. The tables on pp. 18 and 61 of the South Kensington publication *On Some of the Phenomena of New Stars* (Solar Physics Committee, 1914) have been consulted, and some additional coincidences between the lines and bands of the Nova and lines in α Cygni have been noted in the column of Remarks. The origins of the lines are for α Cygni, with some chromospheric lines.

My thanks are due to the Rev. B. Swindells, S.J., for much valuable assistance in the measuring of the plate, and in the reductions of the measures.

Wave-lengths of Dark Lines, and of Bright Lines and Bands in the Spectrum of Nova Aquilæ, 1918 June 10.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
5185	3					84		Positions as far as H obtained by extrapolation.
67	2			5169	6	*69	Fe	
45	2							
18	1							α Cygni lines to 4862 from S. Kensington.
		5080						
		50	8	5057	5			Centre of band.
		25		5019	7	*19	Fe	
5016	3						He	Centre of dark band.
		4970						
		53	8					Centre of bright band.
		37						
4936	3					34	Ba	
4924	4			4924	8	*24	Fe	4922 He.
		4918						
		09	10					Brighter sharp line in band.
		4894						
		4862	9	4862	8			Centre of bright band.
4858	7					62	H	$H\beta_1$.

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
4854	7	4854						$H\beta_2$.
		45	5					Centre of bright band
4844	6							$H\beta_1$.
		36						
4835	1					37		
10	1					11		
4776	3					76		*Ti 4780, S. Ken.
41	1					40		
24	1					23		
10	2					10		4713 He.
		4704	3					
		4674						4674 α Cygni, S. Ken.
4673	2					73		
		4672	3					4667, 4641 α Cygni, S. Ken.
		35						
34	2			4633	1	*34	Cr	S. Ken., α Cygni *4630, *4636 Fe, *4634 Cr.
		4634	3					
		24						4624. *Idem.*
22	2			4622	1	23		
		4620						
		10	5					Centre of bright band.
		4589						
4588	4			4587	1	*88	Cr	
		4588	5					*4584 Fe α Cygni, S. Ken.
		76						Narrow bright band.
74	4					75		
		4574	5					*4577 Fe α Cygni, S. Ken.
		67						Narrow bright band.
52	2					*50	Ti Fe	
		4551	6	4550	1			
		4536						
35	2			4536	2	*34	Ti	*4534 Ti α Cygni, S. Ken.
		4535	5					
		23						
4522	3			4523	3	*23	Fe	
18	1					19		
10	2					*09	Fe	
02	2					*02	Ti	

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
		4502	4					
		4496						
4495	1					95		
90	2			4490	2	*89	Fe	
82	6			81	4	*81	Mg	
71	8					*72	He	
		4469	2	4452	1	*51	Ti	S. Ken., α Cygni 4455 Fe.
		46						
44	3			44	1	*44	Ti	
		4442	3					4434. *Idem.*
		31	4	28	1			Maximum.
		20	3					
17	4			16	4	*18	Ti	4417* Fe.
		16						Bright band crossed
05	1		2			05	Fe	by a dark line.
		4398						
4397	1			4395	2	*95	Ti	
		4394	3			88	He	Helium band.
		85						
83	2			84	5	84	Fe	
		4382	3					
		74						
73	2					73		S. Ken. *4375 Ti.
67	2					*68	Ti	
		4366						Complicated structure
60	1		8			60	Cr	of H_γ bright bands.
52	3			53	3	*52	Cr	S. Ken. *4352 Fe.
		41		41	8	41		
4338	8							H_{γ_1}.
		38	8					
		29						
4326	6							H_{γ_2}.
19	2					19		
13	2			16	2	*13	Ti	
04	1			03	1	*04	Fe	
00	6					*00	Ti	Sharp, strong line.
4292	1					92		S. Ken. *4294 Ti.
87	2					*87		
		4286						
80	1		5	76	1	80		Bright band crossed by a dark line.
		72						

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
4272	1					72	Fe	Close double.
70	1							S. Ken. *4270 Cr.
		4268 61	5					Cr.
4260	1			4262	1	4262*	Cr	
57	1					58		
50	1	55 44	4			50	Fe	Bright band crossed by dark line. S. Kens., 4247 α Cygni, Sc.
43	3			43	2	*43	Cr	
37	1	41 32	5			37		Bright band crossed by dark line.
34	4			34	5	*33	Fe	α Cygni, sharp line.
		30 27	2					Very narrow band.
24	3			27	1	23		S. Ken. *4225 Cr.
21	1					21		
13	2					*12	Zr	
03	2	13	4			03		Bright band crossed by dark absorptions.
00	1					01		
4193	1					4193		
89	1					88		S. Ken. *4188 Ni.
		4180				81	C.	
76	3			4179	6	*79	Fe	α Cygni, broad lines.
72	3			75	6	*72	Ti	*73, Fe.
61	4					*61	Zr	S. Ken. *4164 Ti.
56	1	4160 52	4			*56	Zr	Bright band crossed by dark line.
49	1					*49	Zr	
42	2					*43		4144 He.
36	1	40 31	3			39 36		The H bright band consists of a series of narrow bands crossed by dark lines, and separated by narrow dark spaces.
				30	5	31	Si	
		23		22	1	21	He	
19	1	17	2			19		
						17		

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
		16				15		
4110	1		3	4109	1	*10		S. Ken. *4111 Cr.
		08						
06	3					07		
		06	3					Narrow bright band; edge corresponds to normal position of Hδ.
		02		02	9		Hδ	
4097	10							$H\delta_1$.
4084	10							$H\delta_2$.
		4084						Bright band crossed by dark line.
4079	1		4	4077	1	*79	Ti	
		75						4078 Sr enhanced.
4074	4					74	Fe	S. Ken., α Cygni 4067.
4066	1					*67	Ni	
61	1					61		Close double.
60	2					59		S. Ken. *4058 Fe.
		4057						
		4052	2	4053	1	*54	Ti	Narrow bright band.
50	2							α Cygni; between Hδ and H_ϵ a series of faint bands.
41	3							
		4038						
		33	1			*36	V	
32	2							
26	1			4026	2	27	Ti	He 4026.
21	1					*21	Sc	
09	4			4011	2	09		He 4009.
3999	2			3999	1	*99	Zr V	
		3999						
83	1							
69						70	H	H calcium.
65	10			3969	10	*69	Ca	Centre of dark line.
		63	5					H_ϵ.
61								
58								Dark wing to H.
50								$H\epsilon_1$.
		50						A very bright space.
		46	8					
39	1			3937	1			

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
3933								K calcium.
28	10			3934	7	*34	Ca	
24								
24								Dark wing to K.
16								
16	4							
		3919	5					K_1 displaced.
		14						
3913	8			3913	5	*14	Ti	
		3908	5					
		3902						
				3905	4			S. Ken. *3906 Cr.
3899	7			3899	4	*01	Ti	
		3895	5					
		3888						
3881	9			3889	10		H	$H\zeta_1$ displaced.
3871	8							$H\zeta_2$,,
		3871						
3868	1		4					Bright band crossed by a dark line.
		3863						
3865		3865	1					Series of sharp bright lines in a broad dark band, possibly carbon band.
		3862	1	3862	3	62	Si	
	4	3858	1	55	4	.55	Si	
		53	1	3850	1	50	Ni	S. Ken. *3850 Ni.
49		49	1					
43	2			44	1	44		
		42						
		39				36	$H\eta$	$H\eta$ 3836.
3829				27	3	27		$H\eta_1$ displaced.
20	8							
18	8			19	2	19		$H\eta_2$,,
13	6			13	4	13	Fe	S. Ken. *3915 Ti.
04	1					98	$H\theta$	
3789	8			3787	1	87	V	$H\theta_1$ displaced.
79	7			82	2	82		$H\theta_2$,,
						71	H_ι	
62	8							H_{1} ,,
59	6			60	5	60	Fe	α Cygni double.

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere	Element.	Remarks.
3758	8					52	H_κ	H_{t_2} displaced.
41	8			3741	1	*42	Ti	H_{κ_1} ,,
32	8					34	H_λ	H_{κ_2} ,,
27	8							H_{λ_1} ,,
20	8					22	H_μ	H_{λ_2} ,,
14	8							H_{μ_1} ,,
08	8					12	H_ν	H_{μ_2} ,,
03	8					04	H_ξ	H_{ν_1} ,,
3694	8					97	H_o	H_{ξ_1} H_{ν_2} displaced blend.
89	8					92	H_π	H_{o_1} displaced.
85	8					87	H_ρ	H_{π_1} ,,
81	8					83	H_σ	H_{ρ_1} ,,
76	8					79	H_τ	H_{σ_1} ,,
73	8					76	H_υ	H_{τ_1} ,,
70	8					74	H_ϕ	H_{υ_1} ,,
68	5					71	H_χ	H_{ϕ_1} ,,
65	5							H_{χ_1} ,,
61	5							

Stonyhurst College Observatory:
1918 *November* 1.

The Dark Line Spectrum of Nova Geminorum No. 2.

By Joseph Lunt, D.Sc., F.I.C.

(*Communicated by S. S. Hough, M.A., F.R.S., H.M. Astronomer at the Cape.*)

A by-product of the investigation of the transient dark line spectrum of Nova Aquilæ No. 3 is the unexpected new light which has been thrown on the spectrum of Nova Geminorum No. 2.

Having ascertained that the former spectrum, apart from the strong hydrogen and calcium bands, consisted principally of the enhanced lines of titanium, iron, chromium, scandium, strontium, magnesium, and helium, displaced to the violet by an unprecedented amount, representing a radial velocity of over 1500 kilometres per second on June 11 and 12 (vide *Nature*, **102**, 194), an attempt was made to find lines common to the two spectra. The spectrum of Nova Geminorum has been very fully and care-

fully recorded by Adams and Kohlschutter,* and they give a long list of unidentified dark lines.

In order to visualise the two spectra in juxtaposition they were plotted on millimetre paper.

At first sight they appeared hopelessly dissimilar, but three lines attracted attention by the similarity of their grouping in the two spectra; but the displacement of the group was much smaller in the case of Nova Geminorum.

These lines had been identified in Nova Aquilæ as

Ti_E† 4290·38 Ti_E 4294·20 Ti_E 4300·21

The measures on Plate 5269 June 12 are as under:—

Measured λ in Nova Aquilæ.	Rowland's λ in Sun.	Shift in λ.	Factor km./s per λ.	Shift in km./s.	Corrn. for Shift −1535.‡	Corrected Observed λ.	Observed minus Tabular λ.
4268·18	4290·38	−22·20	69·89	−1552	+21·96	4290·14	−0·24
4272·24	4294·20	21·96	69·83	1533	21·98	4294·22	+0·02
4278·07	4300·21	22·14	69·73	1544	22·01	4300·08	−0·13

Mean displacement −1543 km./s.

On the assumption that the three lines in Nova Geminorum were identical with those in Nova Aquilæ, their displacement was calculated, using Adams and Kohlschutter's wave-lengths for 1912 March 22, 23, 24, with the following result:—

Measured λ in Nova Gem. (A. and K.).	Rowland's λ in Sun.	Shift in λ.	Factor km./s per λ.	Shift in km./s.
4279·5	4290·38	−10·88	69·89	−760
4283·4	4294·20	10·80	69·83	754
4289·1	4300·21	11·11	69·73	775

Mean displacement −763 km./s.

A list of the dark lines in Nova Geminorum was then made, and normal wave-lengths calculated on the basis of a displacement of −763 km./s affecting Adams and Kohlschutter's dark lines.

It was then seen that a considerable number of important lines were common to the spectra of the two Novæ, the mean displacement from twenty-one lines amounting to −777 km.

Table I. gives the normal wave-lengths (undisplaced) of the lines in Nova Aquilæ, the intensities of the lines in the solar and chromospheric spectra and also in Canopus, also the intensities of the enhanced lines from Lockyer's list. The intensities in square brackets are Exner and Haschek's intensities in the spark spectrum of scandium, and the one in curved brackets is Reese's intensity for the enhanced titanium line. The displacement equivalent to −777 km./s is given, and the wave-lengths of the displaced lines are compared with Adams and Kohlschutter's wave-lengths of dark lines in Nova Geminorum.

Considering the small scale of their photographs the agreement is excellent.

* *Ap. J.*, 36, 293. † Ti_E = Titanium enhanced line.

‡ Mean for ten selected lines.

Table I.

Lines common to Nova Aquilæ and Nova Geminorum. (Assuming Adams and Kohlschutter's lines to be displaced −777 km./s.)

Origin in Nova Aquilæ.	Rowland's λ in Sun.	Intensities. Sun (Rowland).	Chromosphere (Dyson).	Canopus (Goatcher).	Enhanced lines (Lockyer).	Factor. Km./s per λ	Shift in λ = −777 km./s.	Displaced line λ.	Nova Gem. λ (A. and K.).	O−C.	Description and Identifications (A. and K.).
* Ti_E	4163·82	4	4	..	10	72·02	−10·78	4153·0	4153·6	+0·6	Centre dark line.
Ti_E	72·07	2	3	..	10	71·87	10·81	61·3	60·4	−0·9	,, faint dark band.
− Fe_E −	4233·33	4	7	7	4–5	70·83	10·97	4222·4	4222·5	+0·1	,, strong dark line.
* Sc_E	47·00	5	10	6	[100]	70·61	11·01	36·0	36·0	0·0	,, dark line.
* Ti_E	90·38	2	5	6	6	69·89	11·12	79·3	79·5	+0·2	,, ,, ,,
* Ti_E	94·20	2	2	6	7	69·83	11·13	83·1	83·4	+0·3	,, ,, ,,
* Ti_E	4300·21	3	5	6	6	69·73	11·14	89·1	89·1	0·0	,, ,, ,,
Ti_E	13·03	3	2	7	7						
Sc	14·25	3	2	7	[30]	69·51	11·18	4302·9	4302·5	−0·4	,, ,, band.
Ti_E	15·14	3	3	7	8						
Ti_E	67·84	2	2	3	5	68·65	11·31	56·5	56·3	−0·2	Dark line.
* Ti_E	95·20	3	8	4	9	68·20	11·40	83·8	84·4	+0·6	,,
Ti_E	99·94	3	2	3	7	68·15	11·40	88·9	89·2	+0·3	,,
Sc	4400·56	3	2	3	[20]						
Ti_E	17·88	3	3	4	6	67·87	11·45	4406·4	4406·4	0·0	,,
* Ti_E	43·98	5	6	4	9	67·48	11·52	32·5	32·3	−0·2	Centre dark band.
* [Ti_E	68·66	5	5	5	9]	67·06	11·59	60·1	60·8	+0·7	Very strong dark line.
He	71·65	..	7	..	..						
* Ti_E	4501·45	5	6	4	8	66·61	11·66	89·8	89·3	−0·5	Dark line (Ti λ 4488·5).
Ti_E	34·14	6	6	5	5	66·13	11·75	4522·4	4522·8	+0·4	Dark line.
Fe_E Ti_E	49·73	2, 6	0, 8	9	7, 8	65·91	11·79	37·9	37·6	−0·3	,,
Fe_E	56·06	3	4	3	5	65·82	11·80	44·3	43·8	−0·5	,,
Cr_E	58·83	3	2	3	10	65·78	11·81	47·0	47·0	0·0	,,
Fe_E	84·02	4	6	5	8	65·41	11·88	72·1	71·9	−0·2	Maxm. in dark band (Ti λ (4572·2).
Cr_E	88·38	3	1	4	10	65·35	11·89	76·5	75·8	−0·7	Dark line.
Ti_E]	4764·11	4	1	..	(4)	62·94	12·34	4751·8	4751·6	−0·2	Maxm. in dark band.
? He	4922·10	..	3†	..	..	60·91	12·76	4910·4	4909·9	−0·5	Centre dark band.
Fe_E	4924·11	5	8	..	8				4911·2	+0·8	Maxm in dark band
? He	5015·73	..	..	..	..	59·77	13·00	5004·2	5004·5	−0·3	Dark line
Fe_E	5018·63	4	7	..	7				5004·2	0·0	(5004·2 on p. 312).

† Involved with Fe 4920·69.

It will be seen that many of the strongest enhanced lines of titanium, iron, and chromium, as well as the strongest scandium line 4247, now fall into place with the prominent helium line 4471, which had been recognised by Adams and Kohlschutter. Moreover, the two lines, assumed by them to be due to titanium, 4488·5 and 4572·2, now appear to be due to titanium 4501·45 and iron 4584·02, both strong enhanced lines, and to show smaller residuals.

It is significant that of ten lines selected in the spectrum of Nova Aquilæ as the best lines for the measurement of radial velocity, eight appear in Table I. as lines in Nova Geminorum, and these are marked by an asterisk.

One of the remaining lines (Ti 4468·66) is probably masked in Nova Geminorum by the helium line 4471·65. In the spectrum of Nova Aquilæ the Cape photographs resolve the pair of lines on the June 12 negatives, when the helium line had become weaker: but in Nova Geminorum the line is probably unresolved. The tenth line is the enhanced strontium line 4215·70, which, displaced −777 km./s, becomes 4204·78. No dark line is recorded in this position by Adams and Kohlschutter on their earliest plates. In their second series there is a dark line at 4206·7. The stronger strontium line 4077·89, which becomes on displacement 4067·32, is also not recorded on the early plates, but there is a dark band at 4067·0 on the plates of the second series.

Lockyer and Baxandall made numerous references to the dark lines in the spectra of Novæ, which show that they doubted the reality of the dark lines as true absorption lines, but in view of the preceding identifications both in Nova Aquilæ and Nova Geminorum their conclusions seem to require revision. The following three references will suffice *:—

> "As, however, it is fairly evident that the Nova spectrum consists chiefly of broad bright lines showing considerable structure in themselves, it seems almost useless to measure the position of each bit of radiation and each bit of apparent absorption, and use the resulting wave-lengths as a means of possibly identifying these bits with lines of chemical elements. Such a method is almost certain to give fictitious and misleading identifications" (p. 34).
>
> "Judging from their narrowness as compared with the width of the well-authenticated bright lines, the latter (interspace interpretation) is more likely to be the real interpretation" (p. 34).
>
> "Between these (radiation lines) are what appear to be narrow absorption lines, but the probability is that these are only gaps between bright lines, and their estimated wave-lengths probably have no significance. At any rate, if these are assumed to be genuine lines, to be consistent one should estimate the positions of each portion of the

* *On Some of the Phenomena of New Stars*, Publications Solar Physics Committee (1914).

dark hydrogen lines, and adopt these as wave-lengths of absorption lines. It is scarcely necessary to point out that such a procedure would give wave-length numbers of no value in so far as identifying the lines of chemical elements is concerned" (p. 36).

It may be pointed out that the third quotation refers to the Madrid spectrum of Nova Geminorum on March 22, and that Adams and Kohlschutter's lines given in Table I. are from negatives taken on March 22, 23, and 24. Baxandall's references to the spectra on the two later days are—23rd, "practically a replica"; 24th, "very similar." So both are dealing with the same spectrum, photographed with different instruments, however.

As opposed to the above views, in Nova Aquilæ and Nova Geminorum I consider we have true absorption spectra. The evidence in Nova Aquilæ is convincing, and without vouching for the genuineness of all the dark lines recorded by Adams and Kohlschutter, very many of which have so far not been identified or even confirmed, the agreement of so many of their lines with well-determined lines in Nova Aquilæ, although with very different displacement, cannot be regarded as fortuitous.

As enhanced titanium lines are so prominent both in Nova Aquilæ and Nova Geminorum, it is of interest to tabulate the strongest of Lockyer's enhanced lines in the region of Table I. In Table II. all the lines of intensity 6 and brighter are given in order of intensity.

TABLE II.

Titanium Enhanced Lines.

	Lockyer's λ		Line Displaced −777 km./s.	Nova Geminorum, 1912 Mar. 22, 23, 24.	O−C.
1	4163·82	10	4153·0	4153·6	+0·6
2	4172·07	10	4161·3	4160·4	−0·9
3	4395·20	9	4383·8	4384·4	+0·6
4	4443·98	9	4432·5	4432·3	−0·2
5	4468·66	9	Involved with helium 4471·65		
6	4572·16	9	4560·3	4562·5	+2·2
7	4338·08	8	Involved with Hγ		
8	4501·45	8	4489·8	4489·3	−0·5
9	4549·81*	8	4537·9	4537·6	−0·3
10	4315·14	8	4302·9	4302·5	−0·4
11	4313·03	7 †			
12	4294·20	7	4283·1	4283·4	+0·3
13	4308·10	7	4296·9	...	...
14	4399·94	7	4388·9	4389·2	+0·3
15	4563·94	7	4552·1	...	...
16	4290·38	6	4279·3	4279·5	+0·2
17	4300·21	6	4289·1	4289·1	0·0
18	4417·88	6	4406·4	4406·4	0·0

* Enhanced iron line involved in Nova Aquilæ.
† Scandium line involved in Nova Aquilæ.

It will be seen that there is only one really discrepant line, viz. Ti 4572·16, and this has not been included in Table I. Two are obviously involved with Hγ, or helium 4471. Two others are unrecorded in the first series. There is a line in the second series at 4551·6, which may be Ti 4563·94 (4552·1 displaced).

All the above have been measured in Nova Aquilæ except 4338·08, which falls on the dark Hγ, but the displacement exceeds − 1500 km./s in the later Nova.

Many more dark lines in Adams and Kohlschutter's spectra might be identified with solar lines due to iron, titanium, chromium, and perhaps calcium, on the supposition that they are displaced − 777 km./s, but the results are of such doubtful value owing to the considerable uncertainties in the wave-lengths of the lines in the Nova and the very large number of lines due to these elements rendering chance coincidences almost certain. It was therefore felt safer to confine this paper to lines about which there can be little doubt, and to the much smaller list of strong enhanced lines. Adams and Kohlschutter have given the displacement in wave-length of the strong hydrogen and helium lines, but have not converted them into radial velocities. In Table III. the radial velocity values are given.

TABLE III.

Dark Hydrogen Lines, First Set (A. and K.).

Origin.	Rowland's λ.	Observed λ.				Shifts in λ.			Factor km./s per λ.	Displacements km./s Mar. 22	23	24
Hε	3970·2	3959	·0	·1		—	−11·2	−11·3	75·53	—	−846	−853
Hδ	4102·0	4090	·2	·6	·8	−11·8	11·4	11·2	73·10	−863	833	819
Hγ	4340·6	4328	·3	·4	·5	−12·3	12·2	12·1	69·08	−850	843	836
Hβ	4861·5	4847	·6	·5	·7	−13·9	14·0	13·8	61·68	−857	864	851
									Means	−857	−847	−840
									Mean		−848	

Helium Absorption Lines, First Set (A. and K.).

Tabular λ.	Observed Mar. 22, 23, 24.	Shift.	Factor.	Km./s.
4143·92	(4133·4)	−10·52	72·36	(−761)
4437·72	(4429·0)	8·72	67·57	(589)
4471·65	4460·8	10·85	67·06	728
4922·10	4911·2	10·90	60·92	664
5015·73	5004·5	11·23	59·78	671
			Mean displacement March 22, 23, 24	−683 km./s.
			,, ,, H and He	−766 km./s.

It will be seen that the hydrogen lines show a velocity consistently higher (negative) than that given by the metallic lines. This might be expected on the supposition that great eruptive

activity prevails, accompanied by outbursts of hydrogen which are in excess of the subsidencies. The displacements of the helium lines are consistently lower, but it is almost certain that the helium lines 4922 and 5016 are blended with enhanced iron lines of uncertain relative intensities on their red sides, and the assumed wave-lengths are too small, giving too low a negative velocity. The effect of this is seen also in the velocity displacement of the bright bands. The identification of the two most refrangible dark helium lines, in brackets, they regard as uncertain.

Just as in Nova Aquilæ, Nova Geminorum shows an extra set of hydrogen and helium lines. The real meaning of these is still obscure. The displacement of the metallic lines corresponds to that of the first set of hydrogen and helium lines.

Read in conjunction with my letter to *Nature*, previously mentioned, it will be evident that I consider these displacements of the enhanced metallic lines as representing real velocities, and that the small velocities previously attributed to Novæ should not be ascribed to the Nova itself, but to the gaseous material left behind by the Nova during its swift passage through a nebula which need not necessarily be, in the first place, gaseous, but may correspond to the dark absorbing material which is so apparent in spiral nebulæ when seen edgewise.

Royal Observatory, Cape of Good Hope:
1918 *Sept.* 28.

The Stellar Magnitude Scales of the Astrographic Catalogue. Thirteenth Note. The Bordeaux Magnitudes ($+17°$, $+16°$, $+15°$, *and* $+14°$). By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. In the twelfth note a considerable amount of material was put into fairly definite shape for the region $-17°$ to $-42°$. Other material is practically ready south of this, but as a very welcome second Melbourne zone ($-67°$) has just been received from Mr. Baldwin, the presentation is deferred. Meanwhile the publication of the Hyderabad zones ($-17°$ and $-18°$) recalled attention to the corresponding portion of the northern hemisphere, especially to the Bordeaux zones, one of which ($+17°$) was studied very early in this series of papers and showed considerable anomalies (*M.N.*, **72**, 464, April 1912).

2. Zones $+16°$, $+15°$, and $+14°$ were counted plate by plate, but not in such detail as zone $+17°$, attention being confined to whole magnitudes instead of half magnitudes, as in Table I. of the paper above cited.

Tables I., II., III. below give the actual counts for each hour

(*not* cumulative counts). At the foot of the columns are given the sums, and then the cumulative counts N′ for the whole 180 plates, followed by their logarithms, log N′. From log N′ is then subtracted the quantity

$$\log 180 \times 4 \times (13/12)^2 = 2{\cdot}93$$

for comparison with the results derived for zone + 17° (*loc. cit.*, p. 466).

TABLE I.

Number of Images recorded under each whole Magnitude in the Catalogue of Bordeaux + 16°.

No. Plates.	Mag. / R.A.	Brighter than 6·0	6·0 and 6·5.	7·0 and 7·5.	8·0 and 8·5.	9·0 and 9·5.	10·0 and 10·5.	11·0 and 11·5.	12·0 and 12·5.	Total.
8	0h	1	2	15	88	284	366	331	35	1122
7	1	1	10	16	77	259	308	323	18	1012
8	2	0	4	19	70	237	300	227	23	880
7	3	1	3	8	68	207	241	173	1	702
8	4	7	5	28	79	195	266	202	7	789
7	5	2	4	19	154	568	776	645	86	2254
8	6	6	15	67	343	1171	1711	1657	320	5290
7	7	3	7	35	171	559	912	940	348	2975
8	8	2	6	15	74	474	636	483	40	1730
7	9	2	8	31	108	227	356	262	13	1007
8	10	3	11	45	154	328	315	271	2	1129
7	11	6	4	31	100	208	241	177	1	768
8	12	0	2	42	93	227	268	177	10	819
7	13	1	0	9	41	137	225	163	10	586
8	14	2	1	9	54	210	296	192	19	783
7	15	5	4	16	73	294	340	216	22	970
8	16	2	5	16	80	309	330	350	73	1165
7	17	4	13	26	66	454	806	572	84	2025
8	18	6	14	54	217	659	1096	931	105	3082
7	19	3	7	22	101	581	1149	1086	272	3221
8	20	1	10	25	155	549	1089	1159	167	3155
7	21	2	1	12	71	356	607	642	94	1785
8	22	1	1	16	80	426	553	547	194	1818
7	23	2	3	24	64	265	396	334	28	1116
180	Sum.	63	140	600	2581	9184	13583	12060	1972	40183
		63	203	803	3384	12568	26151	38211	40183	
	Log N′.	1·80	2·31	2·90	3·53	4·10	4·42	4·58	4·60	
	Log N.	8·87	9·38	9·97	0·60	1·17	1·49	1·65	1·67	

TABLE II.

The same for Zone $+15^{\circ}$.

No. Plates.	Mag. / R.A.	Brighter than 6·0.	6·0 and 6·5.	7·0 and 7·5.	8·0 and 8·5.	9·0 and 9·5.	10·0 and 10·5.	11·0 and 11·5.	12·0 and 12·5.	Total.
7	0^h	3	6	21	82	290	328	272	54	1056
8	1	4	9	28	91	263	351	300	43	1089
7	2	2	2	18	84	226	281	293	45	951
8	3	0	1	3	50	224	262	293	59	892
7	4	4	5	15	70	195	321	233	15	858
8	5	1	8	8	128	504	1104	901	34	2688
7	6	2	1	23	210	950	1841	1407	16	4450
8	7	1	1	8	101	559	1317	1204	64	3255
7	8	0	1	6	61	327	758	579	40	1772
8	9	0	1	8	86	300	499	239	4	1137
7	10	1	0	4	60	221	287	192	26	791
8	11	3	2	7	74	248	280	180	10	804
7	12	0	2	6	37	123	223	117	5	513
8	13	0	0	5	33	150	236	209	28	661
7	14	1	0	4	32	128	246	175	4	590
8	15	3	1	5	48	225	395	257	13	947
7	16	1	2	10	57	229	404	390	44	1137
8	17	3	6	9	90	377	602	488	39	1614
7	18	2	3	20	92	377	650	627	51	1822
8	19	0	3	15	115	524	979	715	71	2422
7	20	4	4	17	130	528	1051	1076	42	2852
8	21	1	2	13	116	455	640	635	61	1923
7	22	0	1	9	81	346	445	468	58	1408
8	23	1	2	16	66	289	363	352	25	1114
180	Sum.	37	63	278	1994	8058	13863	11602	851	36746
	N′.	37	100	378	2372	10430	24293	35895	36746	
	Log N′.	1·57	2·00	2·58	3·37	4·02	4·39	4·56	4·57	
	Log N.	8·64	9·07	9·65	0·44	1·09	1·46	1·63	1·64	

TABLE III.

The same for Zone +14°.

No. Plates.	Mag. / R.A.	Brighter than 6·0.	6·0 and 6·5.	7·0 and 7·5.	8·0 and 8·5.	9·0 and 9·5.	10·0 and 10·5.	11·0 and 11·5	12·0 and 12·5.	Total.
8	0h	1	3	16	67	285	519	416	8	1315
7	1	0	2	4	32	187	252	177	16	670
8	2	0	8	15	82	204	247	285	6	847
7	3	0	0	6	60	286	589	429	7	1377
8	4	1	8	19	98	302	571	340	5	1344
7	5	6	9	19	224	1002	1809	1616	63	4748
8	6	5	8	46	400	1819	4274	4176	143	10871
7	7	1	7	30	217	869	1715	1785	14	4638
8	8	1	9	23	144	373	589	632	36	1807
7	9	0	0	12	88	278	364	292	25	1059
8	10	0	0	5	37	248	445	267	6	1008
7	11	0	1	7	46	154	265	170	7	650
8	12	0	2	2	29	186	348	245	7	819
7	13	0	2	8	52	160	238	199	17	676
8	14	8	6	19	110	269	361	342	5	1120
7	15	2	3	10	59	211	402	403	8	1098
8	16	7	8	33	140	444	509	632	29	1802
7	17	0	6	17	66	340	567	661	84	1741
8	18	7	10	37	132	623	887	1129	372	3197
7	19	5	13	25	122	789	1511	1771	385	4621
8	20	3	4	19	124	570	1372	1504	269	3865
7	21	1	2	9	99	445	635	561	20	1772
8	22	1	2	10	98	434	631	487	17	1680
7	23	1	0	3	62	245	438	299	11	1059
180	Sum.	50	113	394	2588	10723	19538	18818	1560	53784
	N′.	50	163	557	3145	13868	33406	52224	53784	
	Log N′.	1·70	2·21	2·75	3·50	4·14	4·52	4·72	4·73	
	Log N.	8·77	9·28	9·82	0·57	1·21	1·59	1·79	1·80	

3. We may now compare all four zones with Kapteyn's table by the crude method provisionally used in the former paper. [By inadvertence the counts for the brightest stars in zone +17° were commenced with 6·0 instead of with 5·5, so that the first number for zone +17° is only estimated, as it seemed scarcely worth repeating the counts.] The numbers under K_0^{90} are quoted from Kapteyn (*Pub. Ast. Lab., Groningen*, No. 18, Table I.) as before, and differences from them are given for each zone. The differences between the zones are considerable,

especially between zones $+17°$ and $+15°$ and for the bright stars. Thus for the magnitude recorded in the first column as 7·75 (which means all stars recorded in the Bordeaux catalogues as brighter than 8·0), the difference in log N is 0·58, which corresponds to 1·2 magnitudes. Part of this is shown to be a systematic difference between the two zones, either by the mean values at the foot of the table, or by the last column, where differences between zone $+17°$ and $+15°$ are taken. But the difference is by no means a mere constant: the average magnitude *scales* for the two zones differ by quantities far too large to be attributable to anything in the sky.

TABLE IV.

Comparison of Bordeaux Results with Kapteyn's formulæ.

		Bord.—Kap.					
Mag.	K_0^{pg}	$+17°$	$+16°$	$+15°$	$+14°$	Mean.	$17°-15°$
5·75	8·93	(+·24)	−·06	−·27	−·16	(−·08)	+·57
6·75	9·44	+·24	−·06	−·37	−·16	−·09	+·61
7·75	9·93	+·30	+·04	−·28	−·11	−·01	+·58
8·75	0·41	+·38	+·19	+·03	+·16	+·19	+·41
9·75	0·88	+·40	+·29	+·21	+·33	+·31	+·19
10·75	1·34	+·22	+·15	+·12	+·25	+·19	+·10
11·75	1·79	−·04	−·14	−·16	·00	−·09	+·12
All	2·01	−·24	−·34	−·37	−·21	−·29	+·14
Mean		+·19	+·01	−·14	+·01	+·02	+·33

4. Under these circumstances it is disturbing to read in the volume for zone $+16°$:

> "Aucune modification importante n'a été faite ni aux instruments, ni aux procédés; pour ce qui les concerne nous renverrons donc le lecteur à ce premier volume."

The "premier volume" is that for zone $+17°$; so that the differences between $+17°$ and $+16°$, already large, are not referable to any cause traceable in the published particulars. The volume for $+15°$ does not even give this minimum of information, and we are left to presume its repetition.

5. One possible source of discrepancy is open: a table in each volume gives particulars of the plates taken, and of the measurers. Are the differences due perhaps to personality in measuring? A rough count was made of the measurers' initials as follows:—For each plate there are two initials, and in the absence of any distinctive remark, it has been presumed that both ladies were equally concerned with the measures. The three portions into which the

R.A. circuit was divided are quite arbitrary, but are retained as an additional check :—

TABLE V.

Frequency of Different Measures.

	AC / AG	LB / LD	EC	HD	LM	GV
			R.A. $0^h\ 0^m$–$9^h\ 0^m$.			
+17°	20	24	22	21	22	25
+15°	23	17	22	27	24	22
			R.A. $9^h\ 0^m$–$18^h\ 0^m$.			
+17°	17	21	27	26	24	26
+15°	16	27	23	20	18	31
			R.A. $18^h\ 0^m$–$24^h\ 0^m$.			
+17°	12	16	16	16	13	16
+15°	11	13	13	21	10	23
			Total.			
+17°	49	61	65	63	59	67
+15°	50	57	58	68	52	76

The distribution is singularly equable, so that personalities would have to be incredibly large to furnish average differences of the kind noted through the small deviations from uniform distribution.

6. *We are led to infer that there have been changes in method not traceable in the published information, and only recoverable, if at all, at the Observatory itself.* To call attention to such questions affecting the various magnitude scales is the primary object of this series of notes. It is waste of time to investigate the scales by more elaborate methods until one is sure that they are homogeneous enough to be worthy of it. The following information is practically all we have.

On p. 22 of Bordeaux, vol. i. (+17°), it is briefly explained that the magnitudes are estimated by reference to a scale.

> "Avec ces données, les observatrices se sont créé une échelle qui, pour les étoiles comprises entre les grandeurs 9 et 11, leur a permis d'apprécier les grandeurs intermédiaires avec une approximation un peu supérieure à une demi-grandeur. Pour les étoiles brillantes, aucune règle précise n'a été suivie et les nombres donnés n'ont qu'une valeur approximative."

How much is intended by these last words is open to doubt, but it seemed that the scale of magnitudes, though systematically defective for any given plate, was not so erratic but that its correction to a standard scale was contemplated as possible ; for these words follow :—

> ". . . Il est certain que les grandeurs déduites des images photographiques ne sont pas comparables d'une plaque à l'autre et que les grandeurs devront être ultérieurement ramenées à un système plus homogène déduit d'une comparaison avec les grandeurs photométriques des étoiles d'Argelander comprises sur le cliché."

7. The weakness of a comparison with Argelander stars is of course that they do not cover the whole scale. If the scale were uniform with a variable zero only, the zero point might be determined from Argelander stars. But there are apparently considerable deviations from uniformity, which ought first to be traced to their source. The counts for each plate (of which only an hourly summary is above given) are probably much better than the Argelander stars for the purpose of discussion, and a copy of them is at the service of anyone desirous of investigating the matter further.

8. One small point may be mentioned. The very bright stars, such as β Leonis and γ Geminorum, are often omitted from the catalogue as having images too large for measurement. Sometimes there is an explicit note to this effect, but in other cases none. The omissions have been rectified in the counts above given, not without some expenditure of time and trouble. Indeed, it took some time in the first instance (which was that of a star with no note) to realise what had happened.

9. Although the above discordances between the average scales for the different zones prepare us for discordances in detail at least as great and probably greater, the typical reductions have been carried through, as in the last two papers of this series: viz., the correction for galactic latitude has been applied according to the law given in *M.N.*, 78, 57 (Table II.), and residuals formed as in Table IV. of that paper for Cordoba. They are given in the following tables: VI., VII., VIII., IX., the revised results for $+17^\circ$ being included.

TABLE VI.

Residuals of Log N_0 for Zone +17° after correcting for Galactic Condensation.

(The unit is 0·01.)

R.A. h	6·75.	7·75.	8·75.	9·75.	10·75.	All.	Gal. Lat. °
0	−12	−11	− 4	− 6	− 1	− 1	−44·5
1	− 9	−20	−25	+ 3	− 4	−11	−43·5
2	−10	−31	−27	−16	−14	−18	−38·0
3	−35	−38	−31	−30	−24	−23	−29·0
4	−65	−43	−47	−51	−54	−53	−18·5
5	−25	−28	−16	− 7	−10	− 9	− 7·0
6	−34	−13	0	+ 5	+ 5	+ 9	+ 5·5
7	+16	+24	+22	+12	+ 8	+ 9	+18·5
8	+35	+30	28	17	14	+10	+31·5
9	+26	+31	+32	+20	+11	+ 4	+44·5
10	+36	+30	+31	+19	+11	+ 1	+57·5
11	+27	+23	+19	+11	+ 6	+ 9	+71·0
12	+34	+22	+17	+ 7	+10	+23	+79·0
13	− 2	+10	− 2	+ 4	+ 6	+ 9	+75·0
14	+11	+26	+25	+11	+ 4	+ 2	+62·5
15	+16	+ 6	+ 2	− 4	+ 1	+10	+49·5
16	+24	+10	+ 6	0	− 3	+ 7	+36·5
17	+56	+39	+26	+16	+11	+ 6	+23·5
18	+17	+ 6	+ 4	+ 1	− 2	− 2	+10·5
19	+16	+ 4	+ 2	− 1	− 2	− 3	− 2·5
20	−22	+ 5	+ 7	+ 7	+10	+11	−14·5
21	37	−31	−16	0	+ 4	+ 7	−25·5
22	−30	−27	−23	− 2	+ 6	+10	−35·0
23	−25	−23	−26	− 5	− 2	+ 4	−41·5
Mean log N_0	9·90	0·52	1·13	1·67	1·98	2·19	

TABLE VII.

The same for Zone +16°.

R.A. h	6·75.	7·75.	8·75.	9·75.	10·75.	All.	Gal. Lat.
0	−30	−13	+ 3	+ 2	+ 2	+ 3	−45°·5
1	+39	+13	+ 8	+ 5	+ 2	+ 3	−44·5
2	−18	− 4	− 8	−10	−12	−15	−39·0
3	−18	−37	−19	−21	−26	−30	−30·0
4	+17	+ 5	−18	−37	−43	−46	−19·5
5	−19	−27	− 9	− 9	−11	−11	− 8·0
6	+28	+20	+20	+15	+14	+16	+ 4·5
7	+12	+18	+11	+ 6	+ 9	+16	+17·5
8	+ 9	−22	−13	+ 7	+ 8	+ 7	+31·0
9	+35	+33	+25	+ 8	+ 6	+ 3	+44·5
10	+48	+49	+43	+26	+15	+11	+57·5
11	+37	+39	+32	+15	+ 9	+ 4	+70·0
12	−55	+36	+25	+12	+ 8	+ 3	+78·0
13	−82	−33	−19	−16	− 7	− 8	+74·0
14	−29	−30	−14	− 6	− 2	− 5	+62·0
15	+31	+11	+ 8	+12	+ 9	+ 6	+49·5
16	+ 9	−18	− 4	− 2	− 7	− 4	+36·5
17	+43	+24	−12	+ 1	+ 9	+ 9	+23·0
18	+28	+25	+ 7	− 2	− 2	− 1	+ 9·5
19	+ 2	−17	−25	−15	− 6	+ 1	− 3·0
20	+ 7	− 7	− 4	− 6	+ 1	+ 8	−15·0
21	−33	−45	−19	− 5	+ 1	+ 8	−26·5
22	−52	−38	− 8	+ 9	+10	+17	−36·0
23	+ 1	+15	+ 2	+ 3	+ 6	+ 7	−42·5
Mean log N_0	9·54	0·24	0·94	1·57	1·90	2·08	

TABLE VIII.

The same for Zone +15°.

R.A.	6·75.	7·75.	8·75.	9·75.	10·75.	All.	Gal. Lat.
h							
0	+66	+55	+28	+20	+11	+10	−46°·5
1	+77	+63	+29	+13	+ 6	+ 5	−45·5
2	+25	+37	+22	+ 7	− 2	0	−40·0
3	−52	−57	−26	−19	−26	−21	−31·0
4	+45	+21	− 8	−26	−29	−34	−20·0
5	+28	−14	−10	−12	− 7	− 6	− 8·0
6	−15	+11	+15	+17	+20	+18	+ 4·5
7	−31	−28	−10	+ 3	+14	+17	+17·5
8	−46	−25	−10	+ 4	+15	+17	+30·5
9	−47	−11	+12	+12	+13	+ 6	+44·0
10	−41	−31	+ 5	+10	+ 7	+ 4	+57·0
11	+31	+ 6	+14	+14	+ 8	+ 2	+69·0
12	−11	− 4	−11	−11	− 6	−11	+77·0
13	−53	−40	−27	−14	−10	− 6	+73·0
14	−41	−31	−21	−15	− 8	− 9	+62·0
15	+21	−10	−10	− 1	+ 3	+ 1	+49·0
16	+10	+ 9	− 1	− 2	0	+ 4	+35·5
17	+43	+ 6	− 4	− 3	− 5	− 5	+22·5
18	+ 9	+11	−12	−17	−17	−16	+ 9·5
19	−21	−12	−16	−15	−13	−15	− 3·5
20	+36	+18	+ 9	+ 7	+11	+14	−16·0
21	− 4	+ 3	+10	+11	+ 7	+ 8	−27·0
22	−42	− 3	+11	+16	12	+14	−36·5
23	+ 7	+25	+ 7	+ 9	+ 4	+ 6	−43·5
Mean log N_0	9·18	9·88	0·79	1·48	1·86	2·05	

TABLE IX.

The same for Zone +14°.

R.A. h	6·75.	7·75.	8·75.	9·75.	10·75.	All.	Gal. Lat. °
0	+ 2	+17	+ 1	+ 2	+ 5	+ 4	−47·5
1	−24	−35	−33	−17	−19	−22	−46·0
2	+34	+20	+ 6	−12	−22	−23	−40·5
3	−62	−42	−17	− 8	− 2	− 4	−31·5
4	+22	+11	− 8	−22	−22	−29	−20·5
5	+39	+11	+14	+15	+16	+15	− 9·0
6	+25	+27	+30	+31	+38	+40	+ 3·5
7	+19	+26	+25	+22	+25	+28	+17·0
8	+37	+29	+21	+ 3	− 1	0	+30·5
9	−58	− 2	+13	+ 7	0	− 2	+43·5
10	−65	−49	−31	− 6	+ 2	− 3	+56·5
11	−62	−21	−10	−11	− 9	−12	+69·0
12	−36	−64	−42	−14	− 4	− 5	+76·0
13	−28	− 9	− 3	− 7	− 9	− 9	+72·0
14	+66	+45	+32	+14	+ 7	+ 6	+61·0
15	+21	+11	+ 1	− 4	+ 1	+ 3	+48·5
16	+62	+53	+30	+17	+ 7	+ 9	+35·5
17	+12	+10	−15	−14	−13	− 8	−22·0
18	+38	+25	− 6	−11	−17	− 9	+ 8·5
19	+46	+19	− 8	− 1	+ 1	+ 8	− 4·0
20	+ 6	+ 2	− 6	− 6	+ 3	+11	−16·0
21	−15	−15	+ 2	+ 7	+ 3	+ 1	−27·5
22	−14	− 9	+ 7	+13	+10	+ 7	−37·5
23	−58	−55	− 7	− 2	+ 1	− 1	−44·5
Mean log N_0	9·36	0·00	0·87	1·57	1·96	2·16	

10. In Table X. these residuals are harmonically analysed according to precedent. Instead of giving each zone by itself, it has been thought better to collect together corresponding figures for all four zones in order to show clearly the considerable discordances. Further, instead of giving the actual results for each zone, the differences from the mean for the four zones are given. The original coefficients can, of course, be recovered by adding these differences to the mean values.

TABLE X.

Mean harmonic coefficients expressing log N_0 for the four Zones with residual differences for each Zone, in ordinary units.

Zone.	log N_0.	sin θ.	cos θ.	sin 2θ.	cos 2θ.	sin 3θ.	cos 3θ.	sin 4θ.	cos 4θ.
				Stars classified as of mag. 6·75.					
Mean	9·50	− ·066	− ·067	+ ·032	− ·127	+ ·136	+ ·064	+ ·059	+ ·059
+17°	+ ·40	− ·062	− ·211	− ·111	+ ·135	+ ·058	+ ·019	+ ·013	− ·016
+16	+ ·04	+ ·119	+ ·009	− ·089	− ·046	+ ·166	− ·029	− ·129	− ·022
+15	− ·32	+ ·003	+ ·105	+ ·133	+ ·114	+ ·025	− ·065	− ·019	+ ·141
+14	− ·14	− ·059	+ ·097	+ ·066	− ·202	− ·049	+ ·077	+ ·134	− ·111
				Stars classified as of mag. 7·75.					
Mean	0·16	− ·038	− ·056	− ·014	− ·028	+ ·099	+ ·056	+ ·052	+ ·056
+17°	+0·36	− ·058	− ·218	− ·091	+ ·030	− ·001	− ·003	+ ·026	− ·038
+16	+ ·08	+ ·088	− ·092	− ·032	+ ·061	+ ·145	− ·079	− ·082	+ ·094
+15	− ·28	+ ·008	+ ·285	+ ·073	+ ·115	+ ·025	− ·011	− ·008	+ ·065
+14	− ·16	− ·036	+ ·023	+ ·052	− ·204	− ·167	+ ·091	+ ·063	− ·121
				Stars classified as of mag. 8·75.					
Mean	0·93	+ ·013	− ·072	− ·059	+ ·018	+ ·023	+ ·052	+ ·004	+ ·024
+17°	+ ·20	− ·073	− ·164	− ·073	− ·022	+ ·038	− ·001	+0·51	− ·001
+16	+ ·01	+ ·044	− ·045	+ ·004	+ ·059	+ ·070	− ·065	− ·056	+ ·056
+15	− ·14	+ ·018	+ ·169	+ ·021	+ ·069	+ ·039	− ·017	− ·017	+ ·012
+14	− ·06	+ ·010	+ ·041	+ ·048	− ·104	− ·147	+ ·083	+ ·023	− ·067
				Stars classified as of mag. 9·75.					
Mean	1·58	·000	− ·047	− ·080	+ ·030	− ·007	+ ·069	+ ·008	+ ·022
+17°	+ ·11	− ·049	− ·073	− ·032	+ ·001	+ ·034	− ·010	+ ·054	+ ·001
+16	− ·01	+ ·002	− ·027	+ ·004	+ ·021	+ ·041	− ·002	− ·026	+ ·027
+15	− ·10	+ ·020	+ ·081	+ ·004	+ ·047	+ ·023	·000	− ·016	− ·004
+14	− ·01	+ ·026	+ ·020	+ ·023	− ·069	− ·098	+ ·014	− ·014	− ·025
				Stars classified as of mag. 10·75.					
Mean	1·92	− ·011	− ·044	− ·094	+ ·019	− ·028	+ ·069	+ ·022	+ ·025
+17°	+ ·06	− ·052	− ·039	− ·014	+ ·019	+ ·026	− ·010	+ ·028	·000
+16	− ·02	− ·031	− ·010	− ·007	+ ·021	+ ·039	+ ·001	+ ·006	+ ·002
+15	− ·06	+ ·030	+ ·033	− ·001	+ ·024	+ ·018	+ ·017	·000	− ·018
+14	+ ·04	+ ·052	+ ·018	+ ·021	− ·062	+ ·084	− ·010	− ·032	− ·004
				All Stars.					
Mean	2·12	− ·028	− ·035	− ·098	+ ·006	− ·043	+ ·076	+ ·028	+ ·027
+17°	− ·07	− ·056	− ·053	+ ·007	+ ·035	+ ·003	− ·014	+ ·006	+ ·017
+16	− ·04	− ·025	+ ·007	− ·025	+ ·021	+ ·037	+ ·003	+ ·002	+ ·010
+15	− ·07	+ ·041	+ ·039	+ ·008	+ ·024	+ ·022	+ ·024	+ ·006	− ·030
+14	+ ·04	+ ·040	+ ·008	+ ·012	− ·079	− ·063	− ·014	− ·016	+ ·001

11. If now we take the means of the first two means, of the second two, and of the third two, we get—

	$\log N_0$.	$\sin\theta$.	$\cos\theta$.	$\sin 2\theta$.	$\cos 2\theta$.	$\sin 3\theta$.	$\cos 3\theta$.	$\sin 4\theta$.	$\cos 4\theta$.
I.	9·83	−·052	−·062	+·009	−·078	+·118	+·060	+·056	+·058
II.	1·26	+·006	−·060	−·070	+·024	+·016	+·060	+·006	+·023
III.	2·02	−·020	−·040	−·096	+·012	−·034	+·072	+·025	+·026

The first line represents a comparatively small number of stars, and corresponding results have in other zones been excluded. Taking the differences III. − II., we get

$$0{\cdot}76 - {\cdot}026 + {\cdot}020 - {\cdot}026 - {\cdot}012 - {\cdot}050 + {\cdot}012 + {\cdot}019 + {\cdot}003,$$

or reducing to a difference 1·00 in $\log N_0$,

$$1{\cdot}00 - {\cdot}034 + {\cdot}026 - {\cdot}034 - {\cdot}016 - {\cdot}067 + {\cdot}016 + {\cdot}025 + {\cdot}004.$$

12. The first harmonic is the one to which almost exclusive attention has been paid hitherto. It can be put into the form

$$-{\cdot}034\sin\theta + {\cdot}026\cos\theta = -{\cdot}043\cos(\theta - 128^\circ),$$

the phase 128° showing a considerable difference from the calculated ψ of the "spiral," viz.,

$$\psi = 247^\circ - 3{\cdot}66 \times 15^\circ{\cdot}5 = 190^\circ.$$

If we had used the brightest stars (I.) in conjunction with (III.), we should have had

$$+{\cdot}015\sin\theta + {\cdot}010\cos\theta = -{\cdot}018\cos(\theta - 236^\circ),$$

the phase 236° being now on the other side of 190°.

13. But it seems very doubtful, in view of the discordances between the different zones, whether much significance can be attached to these figures. When the single zone +17° was examined in the former paper, the deviations from any possible galactic phenomenon were so large that it seemed unlikely that they could be accidental. But it now appears that zone +15° deviates almost as much in the opposite direction, and there seems no escape from the conclusion that the greater part of the deviations is fortuitous. Further discussion of the figures may in any case be profitably deferred until other material has been tabulated; but a thorough re-examination of the original determinations of magnitude, especially for the bright stars, must clearly precede any attempt to connect the Bordeaux scale of magnitudes with others, for at present there cannot be said to be any definite scale at all!

Z Andromedæ (232848). By T. E. Espin, M.A.

Observations have been made of this interesting object from time to time—those before 1914 with the 17½-in., and the later ones with the 24-in. The comparison stars used were:—

B.D. +48°·4090 8·8 mag.
+48°·4088 9·5 „

1912 Nov. 11, red, spectrum looks like IV., mag. 9·4.
Nov. 29, reddish, spectrum ill-defined, not IV.
1913 Dec. 23, mag. 9·6, apparently deep bands, III.?
1914 Sept. 24, mag. 8·6, very pale yellow. F very bright, and a very dark band on the more refrangible side, and then another bright line?
Sept. 29, mag. 8·4, yellowish. F seen only; F not so bright?
Oct. 27, mag. 8·7, white, could see nothing but continuous spectrum in moonlight.
Nov. 7, mag. 8·3, yellow, could see no bright lines, but suspected faint bands, III.?
Nov. 13, mag. 8·3, yellow. F and another bright line, more refrangible, are seen, but they are now faint.
Nov. 20, mag. 8·3, pale yellow, faint bands in all parts of spectrum. F seen bright, but only with attention.
Dec. 16, mag. 8·7, yellow. I think I glimpse F as bright occasionally, but it is now very faint. There appear to be bands in the spectrum which are, however, faint. Not a good night.
1915 Jan. 9, mag. 8·3, pale orange. F now quite bright, spectrum contains faint bands and looks like faint III.
Sept. 7, mag. 9·8, reddish, bands obvious, III.?
Dec. 8, mag. 9·4, reddish, large faint bands, III.?
1916 Jan. 3, mag. 9·4, reddish. Bands.
Sept. 1, mag. 8·7, red. The spectrum seems full of faint bands, but F is of great brilliancy. A dim spectrum crossed by an intense bright line, F.
Oct. 15, mag. 8·8, red. F the most conspicuous object. Deep bands and spectrum apparently Type IV. Strong moonlight.
Oct. 25, mag. 9·3, red. Deep bands, F only suspected; some haze.
Nov. 21, mag. 9·2, pale red. Type IV., faint.
Dec. 25, mag. 9·2.
1917 Sept. 11, mag. 8·3, very pale orange. Faint bands only.

Some probably Variable Stars. By T. E. Espin, M.A.

The following stars are probably variable :—

No.	B.D.	R.A. 1855.	Decl.	B.D. Mag.	Spectrum.
		h m s	° ′		
1	+44°·788	3 35 2·2	+44 18·7	9·5	III.
2	Anon.	5 38 6·3	+44 48·8	...	IV.
3	+39°·3476	18 33 19·2	+39 32·8	6·5	III.
4	+40°·4001	19 59 16·6	+40 1·5	9·5	IV.
5	+36°·4025	20 15 54·3	+36 28·4	9·5	III.
6	Anon.	45 19·8	+44 52·6	...	IV.
7	+60°·2267	21 31 14·5	+60 16·2	9·5	IV.
8	+41°·4248	38 7·8	+41 26·4	9·4	III.
9	Anon.	23 16 21·1	+44 36	...	IV.
10	+48°·4048	19 41·9	+48 41·8	9·2	IV.
11	Anon.	59 54·9	+43 5·9	...	IV.

Notes.

No. 1.—1915 Jan. 17, 8·9, very red ; Jan. 22, 25, 9·1; Feb. 15, orange-red, 9·0 III.!! 1916 March 4, 8·7.

No. 2.—This is Es-Birm. 156, hitherto wrongly identified ; it is not in the B.D. All the observations are :—1885 Oct. 27, 9·0, red, colour very fine ; Nov. 5, 9·5 ; Nov. 16, 17, 28, Dec. 13, 8·5. 1915 Jan. 9, 9·1; Jan. 25, 9·0. 1916 Nov. 21, 9·1; Dec. 15, 8·9 ; Dec. 26, 8·9.

No. 3.—This is Es-Birm. 555. In *Harvard Annals*, **24**, the photometric mag. is 5·97, and in *Harvard Annals*, **45**, 6·14. The comparison stars used are :—

B.D. +40°·3446	Mag. 6·1	Harvard 6·11
38°·3254	6·5	6·48
38°·3276	6·8	6·81

Observations were made of it, 1916 Oct. 3 to Dec. 26, on 37 nights. It was found to be 6·7 on Oct. 3, but on Oct. 15, 6·3. It remained apparently of nearly the same mag. till the end of the observations on Dec. 26. Observations were resumed this year, and it was observed on 34 nights between 1918 Sept. 24 and Dec. 8. It was only 6·7 on Oct. 11, and continued faint till Nov. 6 : from this date the light gradually increased till on Dec. 8 it was 6·25. In a letter received from Professor E. C. Pickering, he says : "Miss Block has examined twenty-seven plates taken during the last three years and finds that there seems to be slight variation in +39°·3476, which may be real but is within the possibilities of photographic differences in the plates. In comparing the image with stars +39°·3463 and +39°·3479, she finds it is usually about half-way between ; at times +39°·3476 is about as faint as +39°·3479, and on one plate, 1918 Sept. 15, it is about as bright as +39°·3463."

No. 4.—1897 Sept. 24, 9·7. 1914 Nov. 12, 10·5; bands, large and deep, I think Type IV. 1916 Aug. 30, 9·8, banded spectrum ; Sept 1, 10·0, red, Type IV.

No. 5.—This, in Birmingham's first catalogue of red stars, is wrongly identified as B.D. +36°·4028. It was originally found by Webb, and I have searched his MS. observations and found the following entries :—

1876 July 31, Aug. 3, 7, 10, 9·7. 1878 Sept. 11, 9·5; Sept. 25, 10·0.

In the second edition of Birmingham it is rightly identified (No. 664). All my observations are :—

1885 July 9, 9·7. 1886 June 22, 9·0; Aug. 29, 8·7. 1887 April 14, 9·0, very red, var.? 1893 Sept. 16, Type III. 1914 Sept. 17, 8·8, III.!! ; Sept. 20, 8·2, III.! 1916 Sept. 4, 8·3, III.!!

No. 6.—1914 Sept. 15, 9·8, red, IV.!! well seen ; Oct. 26, 9·6. 1915 Dec. 7, 9·8, very red, Type IV. 1916 Nov. 21, 10·0. Comparisons of Barnard's and Wolf's photographs suggest slight variation.

No. 7.—1893 Oct. 11, 9·2, red, Type IV.? 1897 Dec. 18, 9·1, very red, Type IV. 1918 Sept. 10, 10·0; Sept. 30, 10·1, *comes* F., 10·5 ; Oct. 11, 9·8; Oct. 23, 9·8; Nov. 5, 9·4; (Mr. Milburn with the 17½-in. on Nov. 8, 8·9) ; Nov. 11, 9·8; Nov. 13, 9·5; Nov. 19, 9·3. Professor E. C. Pickering informs me that: "Miss Leavitt has examined +60°·2267, and states that this star was suspected of variability in 1910 by Miss L. D. Wells. She examined ten plates taken with the 8-in. Draper telescope, and concluded that they showed slight, if any, evidence of variation. She believed that examination of further plates would show changes. Ten plates, different from those just mentioned, have been examined by Miss D. W. Block. She finds very small fluctuations which seem to be real but do not exceed 0·2 mag. It is usually slightly fainter than the companion mentioned by Mr. Espin, but sometimes equals it in brightness."

Probably in 1893 it was unusually bright.

No. 8.—1916 Sept. 13, 9·1, Type III.!! ; Sept. 23, 8·7; Sept. 24, 8·7; Nov. 21, 9·2; Nov. 24, 8·8; Nov. 27, 9·0; Dec. 15, 8·9.

No. 9.—1918 Sept. 17, 8·8, red, Type IV.!! well seen ; Sept. 20, 9·2; Sept. 29, 9·1. 1915 Dec. 8, 9·5, Type IV. 1916 Sept. 5, 9·4, Type IV.!!

No. 10.—Hitherto wrongly identified as B.D. +48°·4051. 1885 Nov. 16, 9·0. 1894 Oct. 2, 9·0. 1914 Sept. 24, 8·5, red, Type IV.

No. 11.—1916 Jan. 9, 9·4, Type IV.; ditto, Jan. 22; Nov. 21, 10·5; Dec. 19, 9·3, Type IV.

Sur les relations entre les coordonnées rectilignes normales d'une même étoile sur deux clichés différents. Par B. Baillaud.

[*Note by H. H. Turner.*—Nearly a quarter of a century ago, I proposed to use rectilinear co-ordinates for photographic measures in preference to the usual curvilinear co-ordinates. It is difficult at this date to realise the weight of tradition opposed to this simple procedure ; but some idea of it may be caught by recalling that all the formulæ for dealing with micrometric measures (for which rectilinear measures are equally natural) were always laboriously transformed into curvilinear co-ordinates, *e.g.* in correcting for refraction. My note (*M.N.*, **54**, 11) contains a section on the formulæ connecting co-ordinates on one plate

with those on another; but old habit was so strong (even in the reformer himself) that the transformation was made by means of the (really irrelevant) R.A. and N.P.D. as intermediary. I recurred to the subject in 1901 (*M.N.*, 61, 425), still without managing to get rid of the "old man of the sea." During a journey through Paris in November 1918 (soon after the Armistice rendered such a journey possible), M. Baillaud put into my hands the following elegant transformation on rational lines, with the suggestion that it might be printed, if I so wished, in the *Monthly Notices*, which contained the other papers. I gladly acknowledge his courtesy by submitting it for such publication.—H. H. T.]

Problème I.—Deux clichés sont tangents à la sphère céleste de centre C, de rayon p, en des points O_1, O_2. Sur ces clichés, on a tracé des axes de coordonnées rectangulaires : O_1x_1, O_1y_1 ; O_2x_2, O_2y_2. Du centre C on a projeté une étoile S sur les deux clichés en des points S_1, S_2 dont les coordonnées sur les plans des deux clichés sont x_1, y_1 ; x_2, y_2.

La position relative des deux clichés est donnée par les cosinus des angles que les trois droites O_2x_2, O_2y_2, SO_2 font avec les trois droites O_1x_1, O_1y_1, SO_1. On demande les relations entre x_1, y_1 ; x_2, y_2.

Représentons par le tableau suivant les neuf cosinus donnés :

	O_2x_2	O_2y_2	SO_2
O_1x_1	α	λ	ϖ
O_1y_1	β	μ	ρ
SO_1	γ	ν	σ

. . (1)

Ils sont liés par 6 relations distinctes :

$$\left.\begin{array}{ll} \alpha^2+\beta^2+\gamma^2=1 & \alpha\lambda+\beta\mu+\gamma\nu=0 \\ \lambda^2+\mu^2+\nu^2=1 & \alpha\varpi+\beta\rho+\gamma\sigma=0 \\ \varpi^2+\rho^2+\sigma^2=1 & \lambda\varpi+\mu\rho+\nu\sigma=0 \end{array}\right\} \quad . \quad . \quad (2)$$

d'où l'on peut déduire un grand nombre d'autres, notamment

$$\left.\begin{array}{lll} \varpi=\beta\nu-\gamma\mu & \rho=\gamma\lambda-\alpha\nu & \sigma=\alpha\mu-\beta\lambda \\ \alpha=\mu\sigma-\nu\rho & \beta=\nu\varpi-\lambda\sigma & \gamma=\lambda\rho-\mu\varpi \\ \lambda=\rho\gamma-\beta\sigma & \mu=\alpha\sigma-\varpi\gamma & \nu=\varpi\beta-\rho\alpha \end{array}\right\} \quad . \quad (3)$$

Par rapport à trois axes de coordonnées rectangles, SX_1, SY_1, SZ_1, parallèles à O_1x_1, O_1y_1, SO_1, le point S_1 a pour coordonnées x_1, y_1, p; le point S_2: $\alpha x_2+\lambda y_2+\varpi p$; $\beta x_2+\mu y_2+\rho p$; $\gamma x_2+\nu y_2+\sigma p$. Ces deux points et le point S étant en ligne droite, on a :

$$\frac{x_1}{\alpha x_2+\lambda y_2+\varpi p}=\frac{y_1}{\beta x_2+\mu y_2+\rho p}=\frac{p}{\gamma x_2+\nu y_2+\sigma p} \quad . \quad (4)$$

Envisageant trois axes parallèles à O_2x_2, O_2y_2, SO_2, on a de même

$$\frac{x_2}{\alpha x_1+\beta y_1+\gamma p}=\frac{y_2}{\lambda x_1+\mu y_1+\nu p}=\frac{p}{\varpi x_1+\rho y_1+\sigma p} \quad . \quad (5)$$

Ces équations donnent immédiatement x_1, y_1 en fonction de x_2, y_2, et x_2, y_2 en fonction de x_1, y_1.

Problème II.—La position mutuelle des deux clichés sur la sphère étant donnée par les coordonnées, dans le plan de chaque cliché, de la projection, vue de S, du point de contact de l'autre cliché avec la sphère (Turner, *M.N.*, **54**, 22), exprimer en fonction de ces coordonnées les neuf cosinus α, β, γ, λ, μ, ν, ϖ, ρ, σ.

Nous désignerons par ξ_{12}, η_{12} les coordonnées dans le plan du seconde cliché de la projection de O_1 sur ce plan ; par ξ_{21}, η_{21} les coordonnées dans le plan du premier cliché de la projection de O_2 sur ce plan.

Si, dans les équations (4) on suppose $x_2=0$, $y_2=0$, les valeurs correspondantes de x_1, y_1 seront ξ_{21}, η_{21} et l'on aura :

$$\frac{\xi_{21}}{\varpi}=\frac{\eta_{21}}{\rho}=\frac{p}{\sigma}.$$

Si, dans les équations (5) on suppose $x_1=0$, $y_1=0$, les valeurs correspondantes de x_2, y_2 seront ξ_{12}, η_{12} et l'on aura :

$$\frac{\xi_{12}}{\gamma}=\frac{\eta_{12}}{\nu}=\frac{p}{\sigma}.$$

D'où les valeurs de ϖ, ρ, γ, ν :

$$\varpi=\xi_{21}\cdot\frac{\sigma}{p}\,;\quad \rho=\eta_{21}\cdot\frac{\sigma}{p}\,;\quad \gamma=\xi_{12}\cdot\frac{\sigma}{p}\,;\quad \nu=\eta_{12}\cdot\frac{\sigma}{p} \qquad (6)$$

Les formules (2) donnent :

$$\sigma^2\left(\frac{\xi_{21}^2+\eta_{21}^2}{p^2}+1\right)=1 \qquad \sigma^2\left(\frac{\xi_{12}^2+\eta_{12}^2}{p^2}+1\right)=1$$

d'où l'égalité géométriquement évidente :

$$\xi_{21}^2+\eta_{21}^2=\xi_{12}^2+\eta_{12}^2$$

qui exprime que les rayons vecteurs menés du point $(\xi_{21}\eta_{21})$ au centre O_1 et du point $(\xi_{12}\eta_{12})$ au centre O_2 sont égaux. Désignant ces rayons vecteurs par ω, nous aurons :

$$\xi_{21}^2+\eta_{21}^2=\xi_{12}^2+\eta_{12}^2=\omega^2$$

et

$$\frac{\sigma}{p}=\frac{1}{\sqrt{p^2+\omega^2}}.$$

Les équations $\alpha\varpi + \beta\rho = -\gamma\sigma \qquad \alpha\rho - \beta\varpi = -\nu$ donnent ensuite

$$\alpha = -\frac{\eta_{21}\eta_{12}}{\omega^2} - \frac{p\xi_{12}\xi_{21}}{\omega^2\sqrt{p^2+\omega^2}} \qquad \beta = \frac{\xi_{21}\eta_{12}}{\omega^2} - \frac{p\xi_{12}\eta_{21}}{\omega^2\sqrt{p^2+\omega^2}}$$

$$\lambda = \frac{\xi_{12}\eta_{21}}{\omega^2} - \frac{p\xi_{21}\eta_{12}}{\omega^2\sqrt{p^2+\omega^2}} \qquad \mu = -\frac{\xi_{12}\xi_{21}}{\omega^2} - \frac{p\eta_{12}\eta_{21}}{\omega^2\sqrt{p^2+\omega^2}}$$

$$x_2 = p\frac{p\xi_{12} - \frac{x_1}{\omega^2}(p\xi_{12}\xi_{21} + \eta_{12}\eta_{21}\sqrt{p^2+\omega^2}) - \frac{y_1}{\omega^2}(p\xi_{12}\eta_{21} - \xi_{21}\eta_{12}\sqrt{p^2+\omega^2})}{p^2 + \xi_{21}x_1 + \eta_{21}y_1}$$

$$y_2 = p\frac{p\eta_{12} - \frac{x_1}{\omega^2}(p\xi_{21}\eta_{12} - \xi_{12}\eta_{21}\sqrt{p^2+\omega^2}) - \frac{y_1}{\omega^2}(p\eta_{12}\eta_{21} + \xi_{12}\xi_{21}\sqrt{p^2+\omega^2})}{p^2 + \xi_{21}x_1 + \eta_{21}y_1}$$

Si l'on prend p pour unité de longueur, l'homogénéité disparait ; il sera toujours aisé de la rétablir ; on obtient :

$$\text{(A)} \quad x_2 = \frac{\xi_{12} - P_\xi{}^\xi x_1 - P_\xi{}^\eta y_1}{1 + \xi_{21}x_1 + \eta_{21}y_1} \qquad y_2 = \frac{\eta_{12} - P_\eta{}^\xi x_1 - P_\eta{}^\eta y_1}{1 + \xi_{21}x_1 + \eta_{21}y_1}$$

$$\text{(B)} \quad x_1 = \frac{\xi_{21} - P_\xi{}^\xi x_2 - P_\eta{}^\xi y_2}{1 + \xi_{12}x_2 + \eta_{12}y_2} \qquad y_1 = \frac{\eta_{21} - P_\xi{}^\eta x_2 - P_\eta{}^\eta y_2}{1 + \xi_{12}x_2 + \eta_{12}y_2}$$

où l'on a posé

$$P_\xi{}^\xi = \frac{1}{\omega^2}(\xi_{12}\xi_{21} + \eta_{12}\eta_{21}\sqrt{1+\omega^2}) ; \qquad P_\eta{}^\eta = \frac{1}{\omega^2}(\eta_{12}\eta_{21} + \xi_{12}\xi_{21}\sqrt{1+\omega^2})$$

$$P_\xi{}^\eta = \frac{1}{\omega^2}(\xi_{12}\eta_{21} - \xi_{21}\eta_{12}\sqrt{1+\omega^2}) ; \qquad P_\eta{}^\xi = \frac{1}{\omega^2}(\eta_{12}\xi_{21} - \eta_{21}\xi_{12}\sqrt{1+\omega^2}).$$

Il est tout à fait élémentaire d'éliminer ω, ξ_{12}, η_{12}, ξ_{21}, η_{21}, entre ces équations avec $\omega^2 = \xi_{12}^2 + \eta_{12}^2 = \xi_{21}^2 + \eta_{21}^2$. On trouve en quelques lignes

$$(P_\xi{}^\xi P_\eta{}^\eta - P_\xi{}^\eta P_\eta{}^\xi)^2 = (P_\xi{}^\xi)^2 + (P_\eta{}^\eta)^2 + (P_\xi{}^\eta)^2 + (P_\eta{}^\xi)^2 - 1.$$

Problème III.—La position mutuelle des deux clichés sur la sphère étant supposée donnée par la longueur S_1S_2 de l'arc de grand cercle qui joint leurs points de contact, et par les angles S_1, S_2, en S_1 et S_2 dans le triangle sphérique PS_1S_2, qui a pour sommets les points S_1, S_2 et le pôle nord P, calculer les coefficients des relations (A) et (B).

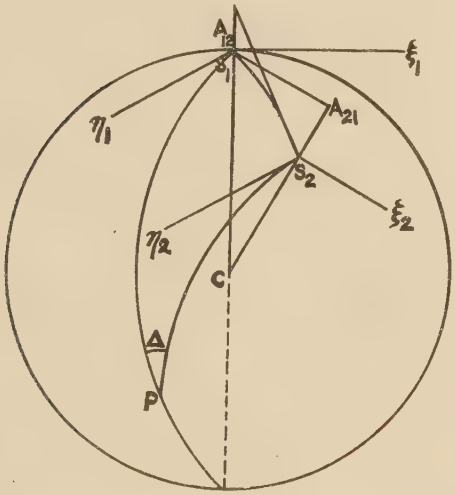
La géométrie donne immédiatement :

$$\xi_{12} = S_2A_{12}\cos S_1S_2\xi_2 = -\operatorname{tg} S_1S_2 \sin S_2$$
$$\eta_{12} = S_2A_{12}\cos S_1S_2\eta_2 = \operatorname{tg} S_1S_2 \cos S_2$$
$$\xi_{21} = S_1A_{21}\cos S_2S_1\xi_1 = \operatorname{tg} S_1S_2 \sin S_1$$
$$\eta_{21} = S_1A_{21}\cos S_2S_1\eta_1 = \operatorname{tg} S_1S_2 \cos S_1$$

d'où

$$\omega = tg S_1S_2$$
$$\sqrt{1+\omega^2} = \text{séc } S_1S_2$$

$$P_\xi^{\ \xi} = -\sin S_1 \sin S_2 + \cos S_1 \cos S_2 \text{ séc } S_1S_2$$
$$P_\xi^{\ \eta} = -\cos S_1 \sin S_2 - \sin S_1 \cos S_2 \text{ séc } S_1S_2$$
$$P_\eta^{\ \eta} = \cos S_1 \cos S_2 - \sin S_1 \sin S_2 \text{ séc } S_1S_2$$
$$P_\eta^{\ \xi} = \sin S_1 \cos S_2 + \cos S_1 \sin S_2 \text{ séc } S_1S_2.$$



Problème IV. — Même question en supposant connues les déclinaisons D_1, D_2 des centres S_1, S_2 des deux clichés et la différence Δ de leurs ascensions droites.

Les relations entre, d'une part, les 2 côtés $90^\circ - D_1$, $90^\circ - D_2$ et l'angle Δ du triangle PS_1S_2, et d'autre part, le 3e côté S_1S_2 et les angles S_1, S_2 donnent immédiatement :

$$P_\xi^{\ \xi} = -\frac{\cos \Delta}{\cos S_1S_2} \qquad P_\eta^{\ \eta} = -\frac{\cos D_1 \cos D_2 + \sin D_1 \sin D_2 \cos \Delta}{\cos S_1S_2}$$

$$P_\xi^{\ \eta} = -\frac{\sin \Delta \sin D_1}{\cos S_1S_2} \qquad P_\eta^{\ \xi} = \frac{\sin \Delta \sin D_2}{\cos S_1S_2}$$

avec $$\cos S_1S_2 = \sin D_1 \sin D_2 + \cos D_1 \cos D_2 \cos \Delta$$

$$\xi_{12} = -\frac{\sin \Delta \cos D_1}{\cos S_1S_2} \qquad \eta_{12} = \frac{\sin D_1 \cos D_2 - \cos D_1 \sin D_2 \cos \Delta}{\cos S_1S_2}$$

$$\xi_{21} = \frac{\sin \Delta \cos D_2}{\cos S_1S_2} \qquad \eta_{21} = \frac{\sin D_2 \cos D_1 - \cos D_2 \sin D_1 \cos \Delta}{\cos S_1S_2}$$

Ces formules ne renferment que les trois quantités D_1, D_2, Δ introduites par H. H. Turner dans son mémoire.*

Il est d'ailleurs aisé d'obtenir directement les formules de H. H. Turner comme il suit :

Deux clichés différents ayant des étoiles communes, trouver les relations existant entre les coordonnées théoriques d'une étoile commune.

Les relations entre ξ, η, α, δ pour un cliché de centre AD, si on les affecte de l'indice 1 pour le premier cliché et de l'indice 2 pour le deuxième, donnent :

$$\xi_1 = \frac{\operatorname{tg}(\alpha - A_1)\sin\phi_1}{\sin(D_1+\phi_1)} \qquad \eta_1 = \operatorname{cotg}(D_1+\phi_1)$$

$$\xi_2 = \frac{\operatorname{tg}(\alpha - A_2)\sin\phi_2}{\sin(D_2+\phi_2)} \qquad \eta_2 = \operatorname{cotg}(D_2+\phi_2)$$

$$\operatorname{tg}\phi_1 = \cos(\alpha - A_1)\operatorname{cotg}\delta$$
$$\operatorname{tg}\phi_2 = \cos(\alpha - A_2)\operatorname{cotg}\delta$$

entre lesquelles on peut éliminer α, δ, ϕ_1, et ϕ_2.

Pour simplifier les écritures, nous poserons :

$$\alpha - A_1 = \alpha'_1 \quad \text{d'où} \quad \alpha - A_2 = \alpha'_1 + A_1 - A_2 = \alpha'_1 - \Delta$$
$$\text{si} \quad \Delta = A_2 - A_1.$$

Les équations deviennent :

$$\xi_1 = \frac{\operatorname{tg}\alpha'_1 \sin\phi_1}{\sin(D_1+\phi_1)} \qquad \eta_1 = \operatorname{cotg}(D_1+\phi_1)\,;\ \operatorname{tg}\phi_1 = \cos\alpha'_1 \operatorname{cotg}\delta$$

$$\xi_2 = \frac{\operatorname{tg}(\alpha'_1 - \Delta)\sin\phi_2}{\sin(D_2+\phi_2)} \qquad \eta_2 = \operatorname{cotg}(D_2+\phi_2)\,;\ \operatorname{tg}\phi_2 = \cos(\alpha'_1 - \Delta)\operatorname{cotg}\delta.$$

Dans ces équations, ϕ_1 et ϕ_2 n'entrent que par leurs tangentes, de sorte que l'élimination de ces quantités est immédiate. Elle donne :

$$\xi_1 = \frac{\sin\alpha'_1 \operatorname{cotg}\delta}{\sin D_1 + \cos D_1 \cos\alpha'_1 \operatorname{cotg}\delta} \qquad \eta_1 = \frac{1 - \operatorname{tg} D_1 \cos\alpha'_1 \operatorname{cotg}\delta}{\operatorname{tg} D_1 + \cos\alpha'_1 \operatorname{cotg}\delta}$$

$$\xi_2 = \frac{\sin(\alpha'_1 - \Delta)\operatorname{cotg}\delta}{\sin D_2 + \cos D_2 \cos(\alpha'_1 - \Delta)\operatorname{cotg}\delta} \qquad \eta_2 = \frac{1 - \operatorname{tg} D_2 \cos(\alpha'_1 - \Delta)\operatorname{cotg}\delta}{\operatorname{tg} D_2 + \cos(\alpha'_1 - \Delta)\operatorname{cotg}\delta}.$$

Si l'on pose : $u = \sin\alpha'_1 \operatorname{cotg}\delta$; $v = \cos\alpha'_1 \operatorname{cotg}\delta$, on a à éliminer u et v entre les 4 équations :

$$\xi_1(\sin D_1 + v\cos D_1) = u\,; \quad \eta_1(\operatorname{tg} D_1 + v) = 1 - \operatorname{tg} D_1 \,.\, v$$
$$\xi_2(\sin D_2 + \cos D_2 \cos\Delta \,.\, v + \cos D_2 \sin\Delta \,.\, u) = \cos\Delta \,.\, u - \sin\Delta \,.\, v$$
$$\eta_2(\operatorname{tg} D_2 + \cos\Delta \,.\, v + \sin\Delta \,.\, u) = 1 - \operatorname{tg} D_2 \cos\Delta \,.\, v - \operatorname{tg} D_2 \sin\Delta \,.\, u.$$

* *M. N.*, 54, 22. En fait, Turner introduit les distances polaires P_1, P_2 au lieu des déclinaisons D_1, D_2.

Les deux premières donnent :

$$v = \frac{1 - \eta_1 \operatorname{tg} D_1}{\eta_1 + \operatorname{tg} D_1}$$

$$u = \xi_1 \frac{\sin D_1 \operatorname{tg} D_1 + \cos D_1}{\eta_1 + \operatorname{tg} D_1} = \frac{\xi_1 \sec D_1}{\eta_1 + \operatorname{tg} D_1}.$$

En remplaçant u et v par ces valeurs dans les 2 autres, elles deviennent :

$$\xi_2 = \frac{-\sin\Delta\cos D_1 + \xi_1\cos\Delta + \eta_1\sin\Delta\sin D_1}{\sin D_2\sin D_1 + \cos D_2\cos D_1\cos\Delta + \xi_1\cos D_2\sin\Delta + \eta_1(\sin D_2\cos D_1 - \cos D_2\sin D_1\cos\Delta)}$$

$$\eta_2 = \frac{\cos D_2\sin D_1 - \sin D_2\cos D_1\cos\Delta - \xi_1\sin D_2\sin\Delta + \eta_1(\cos D_2\cos D_1 + \sin D_2\sin D_1\cos\Delta)}{\sin D_2\sin D_1 + \cos D_2\cos D_1\cos\Delta + \xi_1\cos D_2\sin\Delta + \eta_1(\sin D_2\cos D_1 - \cos D_2\sin D_1\cos\Delta)}.$$

Si l'on permute les indices 1 et 2 et que l'on change, par suite Δ en $-\Delta$, on obtient les expressions de ξ_1 et η_1 en fonction de ξ_2 et η_2

$$\xi_1 = \frac{\sin\Delta\cos D_2 + \xi_2\cos\Delta - \eta_2\sin\Delta\sin D_2}{\sin D_2\sin D_1 + \cos D_2\cos D_1\cos\Delta - \xi_2\cos D_1\sin\Delta + \eta_2(\sin D_1\cos D_2 - \cos D_1\sin D_2\cos\Delta)}$$

$$\eta_1 = \frac{\cos D_1\sin D_2 - \sin D_1\cos D_2\cos\Delta + \xi_2\sin D_1\sin\Delta + \eta_2(\cos D_1\cos D_2 + \sin D_1\sin D_2\cos\Delta)}{\sin D_2\sin D_1 + \cos D_2\cos D_1\cos\Delta - \xi_2\cos D_1\sin\Delta + \eta_2(\sin D_1\cos D_2 - \cos D_1\sin D_2\cos\Delta)}.$$

Ces formules ne renferment que les 3 paramètres Δ, D_1, D_2 introduits par H. H. Turner dans son mémoire (voir la note de la page 8).

Si nous désignons comme précédemment par S_1S_2 la distance des centres S_1, S_2, par S_1 et S_2 les angles en S_1 et S_2 du triangle sphérique PS_1S_2 les formules qui précèdent deviennent celles de Donner : *

$$\xi_2 = \frac{-\sin S_2\sin S_1S_2 + \xi_1\cos\Delta + \eta_1\operatorname{tg} D_1\sin S_1S_2\sin S_2}{\cos S_1S_2 + \xi_1\sin S_1S_2\sin S_1 + \eta_1\sin S_1S_2\cos S_1}$$

$$\eta_2 = \frac{\sin S_1S_2\cos S_2 - \xi_1\operatorname{tg} D_2\sin S_1S_2\sin S_1 + \eta_1(\cos S_1S_2\cos\Delta + \sin S_1\sin S_2\sin^2 S_1S_2)}{\cos S_1S_2 + \xi_1\sin S_1S_2\sin S_1 + \eta_1\sin S_1S_2\cos S_1}.$$

* A remarquer que dans le mémoire de Donner l'angle S_2 est remplacé par son supplément.

On a Shower of Shooting Stars from the Pleiades.

By A. King.

On November 12 last, between $10^h\ 20^m$ and $10^h\ 44^m$, a shower of shooting stars from a radiant within, or very close to, the Pleiades was witnessed by Mr. T. F. Cranidge and the present writer at Ashby, North Lincolnshire. Six meteors in all were seen during the period indicated, in spite of fairly bright moonlight, giving an hourly rate for two observers of 15; but the rate was probably higher than this, since, owing to the shortness of the meteors and the faintness of most of them, several doubtless escaped detection. In a careful watch on the same night from $11^h\ 0^m$ to $11^h\ 52^m$, with a very good sky, only one other object from the centre was seen by the writer, while Mr. Cranidge detected one at about midnight. On referring to the paths recorded on the previous evening in a watch from $10^h\ 55^m$ to $11^h\ 52^m$, with excellent seeing conditions, it was found that two meteors belonging to the same shower had been then observed. Unfortunately, the weather on November 13 was adverse, but nothing was seen of the shower on November 14, neither had it shown any activity on the 10th. There thus seems no doubt that the maximum was well marked in the period November 12, $10^h\ 20^m$ to $10^h\ 44^m$, and I am inclined to set it down specifically as at $10^h\ 40^m$, four meteors having been seen in the five minutes $10^h\ 39^m$ to $10^h\ 44^m$.

The paths registered by the two observers are as under:—

No.	Date.	G.M.T. h m	From	To	Mag.	Dur. sec.	Lgth. °	Notes.	Observer.
1	Nov. 11	11 15	$75\frac{1}{2}+32\frac{3}{4}$	$80+34$	4	...	$3\frac{1}{2}$	R. swift. Dir. from $55°+25°$.	A. K.
2		11 40	$23\frac{1}{2}+21\frac{1}{4}$	$19\frac{1}{2}+20$	4	0·4	4	Dir. from α Arietis.	,,
3	Nov. 12	10 23	$57\frac{1}{2}+43$	$58\frac{1}{4}+46$	1	0·3	$3\frac{1}{4}$	White; starlike. Dir. from $\frac{1}{4}°$ p. η Tauri.	,,
4		10 27	71 +2	74 −3	3	0·5 or 0·6	6		T. F. C.
5		10 39	78 $+11\frac{3}{4}$	82 $+9\frac{1}{4}$	3	0·6 or 0·7	5	Dir. from Aldebaran.	,,
6		10 42	$72\frac{1}{2}+10\frac{1}{3}$	$73\frac{1}{2}+9\frac{3}{3}$	$4\frac{1}{2}$	0·1	1	Dir. from 2° s.p. η Tauri.	A. K.
7		11 17	$76\frac{1}{2}+31\frac{1}{3}$	$81+32\frac{1}{2}$	1	0·3	$3\frac{1}{4}$	Yellow. Dir. from $\frac{1}{4}°$ N. η Tauri.	,,

It seems best to add the flight-directions, as slight errors in reading-off such short paths may cause some considerable divergence in the backward prolongations.

Mr. Cranidge's paths are most likely too long.

The five paths recorded by the writer indicate a radiant at $55°+24\frac{1}{2}°$; including the two mapped by Mr. Cranidge, I should place it at $54°+24°$.

Interest attaches to these observations because, on reference to Mr. Denning's admirable *General Catalogue*, we find several positions similar to those given above grouped under the head of "ζ Perseids"; and, as the true ζ Perseid radiant is at about 50° + 31°, it seemed likely that they had been considered as erratic determinations of that centre.* (A few others are included in the ε Taurids and ζ Arietids.)

The following table contains all the determinations of the place of the radiant which I have been able to collect:—

Position.	No. of Meteors.	Date.	Observer.
54°+28°	...	Aug. 3–12	J. F. J. Schmidt.
55+26	...	,, 3–15	Greg and Herschel.
50+27 51+27	S.S.P.†	,, 21, 1901	A. S. Herschel. W. F. Denning.
53+22	5	Sept. 6–8, 1902	A. S. Herschel.
53+26	...	Oct. 1891	H. Corder.
53+27	18	,, 12, 1868	Schiaparelli—Zezioli.
55+24	13	Oct.–Nov. 1892	H. Corder.
55+27	9	,, ,, 1894	,,
56+24	13	Nov. 1–3, 1872	G. L. Tupman.
56+23	11	,, 1–7, 1869	Denning—Zezioli.‡
53+26	8	,, 4–16, 1890	D. Booth.
56+24	...	,, 6–12, 1871–4	Greg and Herschel.
55+24	...	,, 7–10, 1876	H. Corder.
54+24	...	,, 7–10	,,
55+25	...	,, 13, 1870	Observed at Greenwich.
53+24	4	,, 13, etc., 1891	H. Corder.
52+23	7	,, 13, 1896	Blakeley—Corder.
56+28	6	,, 9–27, 1900	A. S. Herschel.
55+27	...	,, 1891	W. H. Milligan.
55+24½	5	,, 11–12, 1918	A. King.
54+24	7	,, ,, ,,	Cranidge—King.
53+25	F.P. §	Dec. 1, 1912	W. F. Denning.

The mean position, after correcting the individual determinations for precession up to 1918, works out at:—

R.A. 54°·8. Declination +25°·1.

* In a recent letter to the writer, Mr. Denning states that he had so considered them, owing to lack of evidence.

† S.S.P. = shooting-star path.

‡ Erroneously given, on p. 239 of the *General Catalogue*, as Schiap.–Zezioli.

§ F.P. = fireball-path.

The radiants deduced separately by Professor Herschel and Mr. Denning for the same shooting star of 1901 Aug. 21 are not included in this average, as the object may have been a true ζ Perseid.

There seems enough evidence, in my opinion, for the existence of a shower of Pleiadids or η Taurids from $55^\circ + 25^\circ$, closely N. of Alcyone, different from either the ϵ Taurids on the one side, or the ζ Arietids on the other. It is certainly distinct from the ζ Perseids. It would appear to be most active in November, with a probable duration from August to early December (Mr. Denning saw slight traces of it from $55^\circ + 24^\circ$, 1912 Dec. 1–6). The meteors are usually moderate or slow.

Ashby, Scunthorpe, N. Lincs.:
1918 *Dec.* 2.